# NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3119

## STATIC PROPERTIES AND RESISTANCE CHARACTERISTICS OF A FAMILY OF SEAPLANE HULLS HAVING VARYING LENGTH-BEAM RATIO

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## SUMMARY

The static properties and resistance characteristics of a family of seaplane hulls having length-beam ratios from 3 to 20 have been determined. The hydrodynamic stability and rough-water behavior of this family of hulls have been reported previously.

The principal results of the investigation of the static properties are presented in charts from which draft, trim, and upsetting moment for this related series may be obtained for wide ranges of load, center-of-gravity location, and angle of roll. Charts are presented for the determination of resistance and trimming moment for length-beam ratios of 6 and 15.

## INTRODUCTION

In investigating the effects of seaplane-hull proportions, a related series of forms having a wide variation of hydrodynamic length-beam ratio was developed. Wind-tunnel and towing-tank results (refs. 1 to 5) have indicated that relatively high length-beam ratios, desirable for aerodynamic and structural reasons, may be employed without serious impairment of the basic hydrodynamic performance. Inasmuch as the hull lines of the series were found to have generally acceptable hydrodynamic characteristics for length-beam ratios from 6 to 20, the method of derivation of the lines can be used in preliminary design for any desired hull proportions in this range with reasonable assurance that the hydrodynamic qualities will be satisfactory. Unpublished results indicate that the extension of the series to an extremely low length-beam ratio of 3 resulted in a form having acceptable hydrodynamic qualities; therefore, the validity of the method for derivation of the lines for most length-beam ratios of practical importance is further substantiated.

The principal feature in the derivation of the series is the constant length$^2$-beam product which resulted in a family of interchangeable hulls having substantially similar hydrodynamic stability, spray, and take-off performance. An increase in length-beam ratio by this method, however, resulted in improved rough-water characteristics and reduced hull volume and aerodynamic drag.

Application of the derived hull forms of this series to design problems usually necessitates an estimate of the water line at rest, the static rolling moment which has a bearing on the size of lateral stabilizers, and the bare-hull resistance at various speeds during take-off. Experimental data required for these purposes have been obtained in Langley tank no. 1 by using models already available from previously reported wind-tunnel and tank investigations. Inasmuch as the hulls of the series have a constant length$^2$-beam product, these data are presented in the present paper in the form of nondimensional coefficients based on this product. The use of the coefficients facilitates direct comparisons between hulls of different length-beam ratio.

## SYMBOLS

| | |
|---|---|
| $\frac{s}{(l^2b)^{1/3}}$ | center-of-gravity location |
| $C_{d_2}$ | draft coefficient, $d/(l^2b)^{1/3}$ |
| $C_{\Delta_2}$ | load coefficient, $\Delta/wl^2b$ |
| $C_{l_2}$ | rolling-moment coefficient, $\frac{L}{w(l^2b)^{4/3}}$ |
| $C_{M_2}$ | trimming-moment coefficient, $\frac{M}{w(l^2b)^{4/3}}$ |
| $C_{R_2}$ | resistance coefficient, $R/wl^2b$ |
| $C_{V_2}$ | speed coefficient, $\frac{V}{(g)^{1/2}(l^2b)^{1/6}}$ |
| a | longitudinal acceleration, ft/sec$^2$ |
| b | beam, ft |

| | |
|---|---|
| $d$ | draft at step, ft |
| $g$ | acceleration due to gravity, 32.2 ft/sec$^2$ |
| $l$ | distance from bow to sternpost, ft |
| $L$ | rolling moment, lb-ft |
| $M$ | trimming moment, lb-ft |
| $R$ | resistance, lb |
| $s$ | distance forward of step, ft |
| $T$ | excess thrust, lb |
| $V$ | speed, ft/sec |
| $w$ | specific weight of water, 63.4 lb/cu ft for these tests, usually taken as 64.0 lb/cu ft for sea water |
| $\Delta$ | load on water, lb |
| $\Delta_d$ | design gross load, 75,000 lb |
| $\Delta_o$ | gross load, lb |
| $\Delta_t$ | submerged displacement of tip float, lb |
| $\phi$ | angle of roll, deg |
| $\tau$ | trim (angle between forebody keel at step and horizontal), deg |

The subscript 2 used with the coefficients denotes that the coefficient is based on $l^2b$.

## DESCRIPTION OF MODELS, APPARATUS, AND PROCEDURES

Detailed descriptions and offsets of the hulls are presented in the following references:

| Length-beam ratio | Angle of dead rise, deg | Reference |
|---|---|---|
| 6 | 20 | 1 |
| 12 | 20 | 1 |
| 15 | 20 | 1 |
| 15 | 40 | 6 |
| 20 | 20 | 2 |

Offsets of the hull having a length-beam ratio of 3 are given in table I, inasmuch as these offsets have not been published previously.

The hulls have the same depth of step, the same depth of hull and ratio of forebody to afterbody length, and the same length$^2$-beam product. The wing was located in the same position relative to the step of the hulls. Pertinent characteristics and dimensions are given in table II.

All dimensions are full size unless noted otherwise.

## Static Properties

The hulls available for the determination of the static properties were those from the $\frac{1}{10}$-size powered dynamic models which were used in the investigations of the hydrodynamic qualities. The test setup is shown in figure 1. The models were free to trim about the pivot, which was located at the center of gravity, and were free to move vertically but were restrained in roll and yaw. The angle of roll, however, could be set at any desired angle. Trim and angle of roll were indicated by the inclinometers, and rolling moment by the dial indicator shown in figure 1. A stable rolling moment (righting moment) is considered positive, an unstable moment (upsetting moment) negative. Scales on the forebody and afterbody indicated the draft.

Data were obtained for a range of gross load from 45,000 pounds to 105,000 pounds, full size. With the model at zero angle of roll, the trim and draft of all the hulls (length-beam ratios from 3 to 20) were determined over a range of center-of-gravity location. The trim, draft, and upsetting moments were measured for all of the hulls at fixed angles of roll up to 10° at one center-of-gravity location. Similar data also were obtained at two additional center-of-gravity locations for the hull having a length-beam ratio of 15 and angle of dead rise of 20°.

### Resistance Characteristics

The hulls used in the resistance investigation were those from the $\frac{1}{10}$ - size wind-tunnel models (ref. 1) and had length-beam ratios of 6 and 15 with angles of dead rise of 20°. The test procedure and towing equipment are described in reference 7. The models were pivoted at the center of gravity and were free to move vertically but were restrained in roll and yaw. The center of gravity of the model was located 15.5 inches above the keel at the step and 2.73 inches forward of the step (32 percent mean aerodynamic chord).

The resistance and trimming moments were measured for a range of speed and fixed trim sufficient to determine minimum resistance for a range of load. The aerodynamic drag of the hulls was included in the final resistance. The tares of the towing gate were subtracted from the gross resistance. Moments tending to raise the bow are considered positive and are referred to the center-of-gravity location defined previously.

## RESULTS AND DISCUSSION

### Static Properties

Longitudinal static properties.- The longitudinal static properties are presented in figure 2 as plots of trim and draft coefficient against load coefficient for five center-of-gravity locations. The location of the center of gravity relative to the mean aerodynamic chord, the distance forward of the step, and the distance from the bow are given in table III. Within the wide ranges of load, center-of-gravity location, and angle of dead rise investigated, the trim and draft for this related series may be determined from figure 2 for length-beam ratios from 3 to 20.

Transverse static properties.- Inasmuch as the variations of trim and draft with angle of roll were negligible, these data are not presented. The trim and draft data at zero roll (fig. 2) may be used for angles of roll up to 10°.

A typical variation of rolling-moment coefficient (upsetting moment) with angle of roll is presented in figure 3. For practical purposes, the upsetting moment increased linearly with increase in angle of roll for all loads and all length-beam ratios.

The effect of length-beam ratio on the slope of the linear rolling-moment curves is shown in figure 4, where the rolling-moment coefficient divided by the angle of roll in degrees is plotted against load coefficient. The upsetting moment for this related series of hulls at any angle of roll for length-beam ratios from 3 to 20 may be estimated from this figure. Upsetting moment increased with increase in length-beam ratio, but the rate of increase was less at the higher length-beam ratios. At load coefficients less than 0.025, the hull with a length-beam ratio of 3 was statically stable at all angles of roll up to $10^{\circ}$. At the design load of 75,000 pounds $\left(C_{\Delta_2} = 0.0262\right)$, the hull of length-beam ratio 3 was statically stable for angles of roll less than $3^{\circ}$.

The effect of center-of-gravity location and angle of dead rise on the slope of the rolling-moment curve is shown in figure 5. In general, either a rearward shift of the center of gravity or an increase in angle of dead rise from $20^{\circ}$ to $40^{\circ}$ gave a small reduction in the upsetting moment.

As a measure of the relative transverse stability of the hulls with different length-beam ratios, the tip-float displacement required to overcome the upsetting moment due to gravity and that required to provide the gross righting moment required by U. S. Navy specifications for transverse stability of seaplanes (ref. 8) have been determined for an angle of roll of $7^{\circ}$ at the design gross load. The gross righting moment as specified by the Navy includes the upsetting moment due to gravity and factors for the effects of wind and waves. The ratio of the tip-float displacement to design gross load required to overcome the upsetting moment and to provide the gross righting moment is plotted against length-beam ratio in figure 6. The required tip-float displacement increased rapidly with increase in length-beam ratio from 3 to 6. Further increase in length-beam ratio caused a relatively small increase in tip-float displacement. As shown in figure 6, the increase in tip-float displacement required to overcome the upsetting moment with increase in length-beam ratio was relatively small compared with that part of the tip-float displacement required for the effects of wind and waves.

## Resistance Characteristics

Charts for the determination of the resistance and trimming moment of hulls with length-beam ratios of 6 and 15 are presented in figures 7(a) and 7(b), respectively. This type of chart is discussed in detail in reference 9.

The resistance and trimming-moment coefficients, and trim at best trim (that is, trim for minimum resistance) are presented in figure 8. At the speed for hump resistance, the resistance was approximately the same for both length-beam ratios, but the hump resistance occurred at a higher speed for a length-beam ratio of 15 than for a length-beam ratio of 6. Trimming moments at hump speed increased with increase in length-beam ratio. The trimming moment was approximately zero at high speeds for both length-beam ratios.

In general, the trends of the results are in good agreement with those described in reference 10 for length-beam ratios from 5 to 9.

## Take-Off Calculations

The take-off performance at several values of the gross load has been calculated in order to determine the effect of length-beam ratio on take-off time and distance and on the maximum overload at which a take-off can be made. The procedure used for the take-off calculations is described in reference 11.

The flying boats were assumed to be free to trim at speeds up to the speed for hump resistance, to be at trims slightly greater than the lower trim limit of stability just above hump speed, and to be at best trim for the rest of the take-off.

Aerodynamic data from tests of the dynamic model (ref. 3) were used to determine the aerodynamic lift and pitching moments. During tests of the powered dynamic model, the resultant horizontal force (equivalent to effective thrust minus aerodynamic drag of model without power) was determined for take-off power with the model suspended beneath the towing carriage and just above the surface of the water. These data, which previously have not been published, are presented in figure 9.

Data showing the variation of the excess thrust and trim with speed for a take-off at the design gross load are presented in figure 10. The excess thrust is the resultant horizontal force plus the aerodynamic drag of the model without power minus the resistance of the hull. Similar data from tests of the dynamic model (ref. 3) are included also. The excess thrust and trim determined from the resistance test are in good agreement with the dynamic-model data. The take-off time and distance were derived from the excess-thrust curves by use of the relationship

$$a = \frac{Tg}{\Delta_o}$$

The take-off time and distance at the design gross load are compared in the following table:

| Model | Time, sec, (full size) for - | | Distance, ft, (full size) for - | |
|---|---|---|---|---|
| | $\frac{l}{b} = 6$ | $\frac{l}{b} = 15$ | $\frac{l}{b} = 6$ | $\frac{l}{b} = 15$ |
| Dynamic model, (ref. 3) | 22.0 | 21.0 | 1,600 | 1,530 |
| Resistance hull | 21.9 | 20.7 | 1,570 | 1,495 |

The effect of gross load on the take-off performance is shown in figure 11 where the excess thrust at take-off speed, and the take-off time and distance are plotted against gross load. On the basis of available thrust for acceleration (fig. 11(a)), it can be concluded that the hull with a length-beam ratio of 15 will take off at an overload approximately 7 percent greater than that for a hull with a length-beam ratio of 6. At the design gross load, the take-off time and take-off distance are approximately 5 percent less for the hull with the high length-beam ratio. Because of limitations in load imposed by excessive spray, the recommended overload for both hulls is 95,000 pounds (ref. 12). At this limiting load, the take-off time was 17 percent less and the take-off distance 20 percent less for the hull with the high length-beam ratio.

## CONCLUDING REMARKS

The principal results of an experimental investigation of the static properties of a family of hulls having length-beam ratios varying from 3 to 20 are presented as plots of trim, draft coefficient, and rolling-moment coefficient against load coefficient. The draft, trim, and upsetting moment for this related series may be obtained from these plots for wide ranges of load, center-of-gravity location, and angle of roll. Upsetting moment increased with increase in length-beam ratio, but the rate of increase was less at the higher length-beam ratios. The required tip-float displacement increased rapidly with increase in length-beam ratio from 3 to 6. Further increase in length-beam ratio caused a relatively small increase in required tip-float displacement.

Charts are presented for the determination of resistance and trimming moment for length-beam ratios of 6 and 15 of a related series of hulls. At the speed for hump resistance, the resistance was approximately the same for both length-beam ratios, but the hump resistance occurred at a higher speed for the length-beam ratio of 15 than for the length-beam ratio of 6. At the design load, the take-off time and distance decreased approximately 5 percent with an increase in length-beam ratio from 6 to 15.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 20, 1953.

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TABLE I

OFFSETS FOR LENGTH-BEAM-RATIO-3 HULL

[$\frac{1}{10}$ - size model; all dimensions are in inches]

| Station | Distance to F.P. | Height of keel above base line | Height of chine above base line | Half beam at chine | Half maximum beam | Height of hull at center line | Line of centers above base line | Angle of chine flare, deg | Height above base line | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Buttocks | | | | | | | | |
| | | | | | | | | | 1.05 | 2.08 | 3.13 | 4.16 | 5.21 | 6.24 | 7.28 | 8.32 | 9.36 |
| F.P. | 0 | {10.30, 10.90} | 10.90 | 0 | 0 | 10.92 | | | | | | | | | | | |
| 1/2 | 1.48 | 5.49 | 10.60 | 4.78 | 4.78 | 14.29 | | 10 | 7.55 | 9.63 | 10.53 | 10.71 | | | | | |
| 1 | 2.94 | 3.76 | 9.90 | 6.36 | 6.36 | 15.72 | | 10 | 5.35 | 6.97 | 8.58 | 9.58 | 10.03 | 9.92 | | | |
| 2 | 5.89 | 1.83 | 7.58 | 8.03 | 8.03 | 17.35 | | 10 | 3.02 | 4.18 | 5.87 | 6.37 | 7.13 | 7.59 | 7.07 | | |
| 3 | 8.84 | .80 | 5.88 | 8.98 | 8.98 | 18.41 | | 10 | 1.66 | 2.55 | 3.42 | 4.32 | 5.07 | 5.58 | 5.89 | 5.96 | |
| 4 | 11.79 | .27 | 4.62 | 9.59 | 9.59 | 19.12 | | 10 | .94 | 1.62 | 2.30 | 3.00 | 3.63 | 4.16 | 4.56 | 4.75 | 4.67 |
| 5 | 14.73 | .04 | 3.72 | 9.97 | 9.97 | 19.60 | | 10 | .56 | 1.10 | 1.63 | 2.12 | 2.66 | 3.12 | 3.50 | 3.74 | 3.80 |
| 6 | 17.67 | 0 | 3.14 | 10.17 | 10.17 | 19.88 | | 5 | .40 | .83 | 1.22 | 1.62 | 2.03 | 2.44 | 2.76 | 3.05 | 3.16 |
| 7 | 20.62 | 0 | 2.90 | 10.24 | 10.24 | 19.99 | | 0 | .38 | .75 | 1.14 | 1.52 | 1.92 | 2.27 | 2.56 | 2.76 | 2.90 |
| 8 | 23.57 | 0 | 2.90 | 10.25 | 10.25 | 20.00 | | 0 | .38 | .75 | 1.14 | 1.52 | 1.92 | 2.27 | 2.56 | 2.76 | 2.90 |
| 9 | 26.52 | 0 | 2.90 | 10.25 | 10.25 | 20.00 | | 0 | .38 | .75 | 1.14 | 1.52 | 1.92 | 2.27 | 2.56 | 2.76 | 2.90 |
| 10 | 29.46 | 0 | 2.90 | 10.25 | 10.25 | 20.00 | | 0 | .38 | .75 | 1.14 | 1.52 | 1.92 | 2.27 | 2.56 | 2.76 | 2.90 |
| 11 | 32.40 | 0 | 2.90 | 10.25 | 10.25 | 20.00 | | 0 | .38 | .75 | 1.14 | 1.52 | 1.92 | 2.27 | 2.56 | 2.76 | 2.90 |
| 12F | 35.38 | 0 | 2.90 | 10.25 | 10.25 | 20.[illegible] | | 0 | .38 | .75 | 1.14 | 1.52 | 1.92 | 2.27 | 2.56 | 2.76 | 2.90 |
| 12A | 35.38 | 1.16 | 4.89 | 10.25 | 10.25 | 20.00 | | | 1.54 | 1.90 | 2.28 | 2.66 | 3.04 | 3.41 | 3.80 | 4.17 | 4.55 |
| 13 | 38.30 | 1.44 | 5.11 | 10.09 | 10.09 | 20.00 | | | 1.82 | 2.19 | 2.57 | 2.95 | 3.32 | 3.70 | 4.07 | 4.45 | 4.84 |
| 14 | 41.24 | 1.71 | 5.23 | 9.67 | 9.67 | 20.00 | | | 2.10 | 2.47 | 2.86 | 3.23 | 3.60 | 3.97 | 4.36 | 4.74 | 5.12 |
| 15 | 44.19 | 1.99 | 5.28 | 9.05 | 9.05 | 20.00 | | | 2.36 | 2.74 | 3.12 | 3.48 | 3.86 | 4.24 | 4.63 | 5.00 | |
| 16 | 47.13 | 2.27 | 5.27 | 8.24 | 8.24 | 20.00 | | | 2.64 | 3.01 | 3.39 | 3.75 | 4.14 | 4.52 | 4.90 | 5.26 | |
| 17 | 50.08 | 2.55 | 5.19 | 7.25 | 7.25 | 20.00 | | | 2.89 | 3.27 | 3.65 | 4.02 | 4.40 | 4.77 | 5.16 | | |
| 18 | 53.03 | 2.83 | 5.00 | 5.97 | 5.97 | 20.00 | | | 3.17 | 3.54 | 3.92 | 4.28 | 4.67 | | | | |
| 19 | 55.97 | 3.11 | 4.67 | 4.29 | 4.29 | 20.00 | | | 3.46 | 3.83 | 4.21 | 4.59 | | | | | |
| 20 | 58.92 | 3.39 | 4.19 | 2.21 | 3.15 | 20.00 | | | 3.73 | 4.11 | | | | | | | |
| S.P. | 61.47 | 3.63 | 3.63 | 0 | 3.00 | 20.00 | 17.00 | | | | | | | | | | |
| 21 | 68.75 | | | | 2.55 | 20.00 | 17.45 | | | | | | | | | | |
| 22 | 72.46 | | | | 2.32 | 20.90 | 17.68 | | | | | | | | | | |
| 23 | 76.17 | | | | 2.09 | 22.79 | 17.91 | | | | | | | | | | |
| 24 | 79.88 | | | | 1.87 | 22.79 | 18.13 | | | | | | | | | | |
| 25 | 83.59 | | | | 1.64 | 22.79 | 18.36 | | | | | | | | | | |
| 26 | 87.30 | | | | 1.41 | 22.79 | 18.59 | | | | | | | | | | |
| 27 | 91.02 | | | | 1.18 | 22.79 | 18.82 | | | | | | | | | | |
| 28 | 94.73 | | | | .95 | 22.79 | 19.05 | | | | | | | | | | |
| 29 | 98.44 | | | | .73 | 22.79 | 19.27 | | | | | | | | | | |
| A.P. | 100.99 | | | | .57 | 20.00 | 19.43 | | | | | | | | | | |

| Station | Distance from center line | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Water line | | | | | | | | | | | | |
| | 5.50 | 8.43 | 10.00 | 11.00 | 12.00 | 13.00 | 14.00 | 15.00 | 16.00 | 17.00 | 18.00 | 19.00 | 20.00 |
| F.P. | | | | | | | | | | | | | |
| 1/2 | 0 | 1.48 | 2.35 | 4.52 | 3.80 | 2.83 | 1.20 | | | | | | |
| 1 | 1.15 | 3.04 | {5.00, 6.09, 6.26} | 5.72 | 5.11 | 4.35 | 3.42 | 2.17 | | | | | |
| 2 | 3.25 | 7.83 | 7.25 | 6.75 | 6.20 | 5.56 | 4.84 | 4.00 | 3.00 | 1.60 | | | |
| 3 | 6.04 | 8.62 | 8.00 | 7.51 | 6.97 | 6.40 | 5.75 | 5.03 | 4.21 | 3.21 | 1.83 | | |
| 4 | 9.60 | 9.25 | 8.64 | 8.17 | 7.64 | 7.07 | 6.45 | 5.77 | 5.01 | 4.15 | 3.07 | 1.01 | |
| 5 | 9.97 | 9.65 | 9.06 | 8.62 | 8.11 | 7.55 | 6.36 | 6.30 | 5.55 | 4.71 | 3.71 | 2.35 | |
| 6 | 10.17 | 9.86 | 9.31 | 8.89 | 8.40 | 7.85 | 7.25 | 6.61 | 5.87 | 5.04 | 4.12 | 2.90 | |
| 7 | 10.25 | 9.95 | 9.42 | 9.01 | 8.51 | 7.98 | 7.40 | 6.76 | 6.03 | 5.20 | 4.28 | 3.10 | 0 |
| 8 | 10.25 | 9.95 | 9.42 | 9.01 | 8.51 | 7.98 | 7.40 | 6.76 | 6.03 | 5.20 | 4.28 | 3.10 | 0 |
| 9 | 10.25 | 9.95 | 9.42 | 9.01 | 8.51 | 7.98 | 7.40 | 6.76 | 6.03 | 5.20 | 4.28 | 3.10 | 0 |
| 10 | 10.25 | 9.95 | 9.42 | 9.01 | 8.51 | 7.98 | 7.40 | 6.76 | 6.03 | 5.20 | 4.28 | 3.10 | 0 |
| 11 | 10.25 | 9.95 | 9.42 | 9.01 | 8.51 | 7.98 | 7.40 | 6.76 | 6.03 | 5.20 | 4.28 | 3.10 | 0 |
| 12F | 10.25 | 9.95 | 9.42 | 9.01 | 8.51 | 7.98 | 7.40 | 6.76 | 6.03 | 5.20 | 4.28 | 3.10 | 0 |
| 12A | 10.25 | 9.95 | 9.42 | 9.01 | 8.51 | 7.98 | 7.40 | 6.76 | 6.03 | 5.20 | 4.28 | 3.10 | 0 |
| 13 | 10.09 | 9.83 | 9.40 | 9.01 | 8.51 | 7.98 | 7.40 | 6.76 | 6.03 | 5.20 | 4.28 | 3.10 | 0 |
| 14 | 9.67 | 9.55 | 9.24 | 8.92 | 8.48 | 7.98 | 7.40 | 6.76 | 6.03 | 5.20 | 4.28 | 3.10 | 0 |
| 15 | 9.05 | 9.01 | 8.88 | 8.69 | 8.39 | 7.92 | 7.38 | 6.76 | 6.03 | 5.20 | 4.28 | 3.10 | 0 |
| 16 | 8.24 | 8.22 | 8.19 | 8.10 | 7.95 | 7.65 | 7.27 | 6.70 | 6.03 | 5.20 | 4.28 | 3.10 | 0 |
| 17 | 7.25 | 7.22 | 7.20 | 7.18 | 7.16 | 7.00 | 6.75 | 6.50 | 5.73 | 5.05 | 4.18 | 3.03 | 0 |
| 18 | 5.97 | 5.97 | 5.97 | 5.97 | 5.97 | 5.94 | 5.81 | 5.55 | 5.10 | 4.55 | 3.78 | 2.77 | 0 |
| 19 | 4.29 | 4.29 | 4.29 | 4.29 | 4.29 | 4.27 | 4.23 | 4.10 | 3.82 | 3.45 | 3.08 | 2.41 | 0 |
| 20 | 2.22 | 2.22 | 2.22 | 2.22 | 2.22 | 2.19 | 2.15 | 2.50 | 3.02 | 3.15 | 2.95 | 2.31 | 0 |
| S.P. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | |

TABLE II

PERTINENT CHARACTERISTICS AND DIMENSIONS OF LANGLEY TANK NO. 1 SERIES OF LENGTH-BEAM-RATIO HULLS

[Dimensions are full size]

| | Length-beam ratio | | | | | |
|---|---|---|---|---|---|---|
| | 3 | 6 | 12 | a15 | b15 | 20 |
| Hull: | | | | | | |
| Maximum beam, ft | 17.08 | 10.76 | 6.78 | 5.84 | 5.84 | 4.82 |
| Length: | | | | | | |
| Forebody, bow to step, ft | 29.48 | 37.15 | 46.81 | 50.43 | 50.43 | 55.51 |
| Afterbody, step to sternpost, ft | 21.74 | 27.39 | 34.52 | 37.18 | 37.18 | 40.93 |
| Tail extension, sternpost to aft perpendicular, ft | 32.93 | 27.28 | 20.16 | 17.49 | 17.49 | 13.74 |
| Over-all, bow to aft perpendicular, ft | 84.15 | 91.82 | 101.49 | 105.10 | 105.10 | 110.18 |
| Length-beam ratio: | | | | | | |
| Forebody | 1.73 | 3.45 | 6.91 | 8.64 | 8.64 | 11.51 |
| Afterbody | 1.27 | 2.55 | 5.09 | 6.36 | 6.36 | 8.49 |
| Step: | | | | | | |
| Type | Transverse | Transverse | Transverse | Transverse | Transverse | Transverse |
| Depth at keel, in. | 11.60 | 11.60 | 11.60 | 11.60 | 11.60 | 11.60 |
| Depth at keel, percent beam | 5.66 | 8.98 | 14.27 | 16.55 | 16.55 | 20.07 |
| Angle of forebody keel with respect to base line, deg | 0 | 0 | 0 | 0 | 0 | 0 |
| Angle of afterbody keel with respect to base line, deg | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 |
| Angle of sternpost with respect to base line, deg | 7.9 | 7.4 | 7.0 | 6.9 | 6.9 | 6.7 |
| Angle of dead rise of forebody: | | | | | | |
| Excluding chine flare, deg | 20 | 20 | 20 | 20 | 40 | 20 |
| Including chine flare, deg | 15.8 | 15.8 | 15.8 | 15.8 | 33.3 | 15.8 |
| Angle of dead rise of afterbody, deg | 20 | 20 | 20 | 20 | 40 | 20 |
| Center-of-gravity height, ft | 12.91 | 12.91 | 12.91 | 12.91 | 12.91 | 12.91 |
| Wing: | | | | | | |
| Span, ft | 139.7 | 139.7 | 139.7 | 139.7 | 139.7 | 139.7 |
| Root chord, ft | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 |
| Mean aerodynamic chord: | | | | | | |
| Length, projected, ft | 13.7 | 13.7 | 13.7 | 13.7 | 13.7 | 13.7 |
| Distance of leading edge aft of bow, ft | 22.8 | 30.5 | 40.1 | 43.7 | 43.7 | 48.8 |
| Distance of leading edge forward of step, ft | 6.7 | 6.7 | 6.7 | 6.7 | 6.7 | 6.7 |
| Distance of leading edge above base line, ft | 15.1 | 15.1 | 15.1 | 15.1 | 15.1 | 15.1 |
| Angle of incidence, deg | 4 | 4 | 4 | 4 | 4 | 4 |

[a]Length-beam ratio of 15 with 20° angle of dead rise.

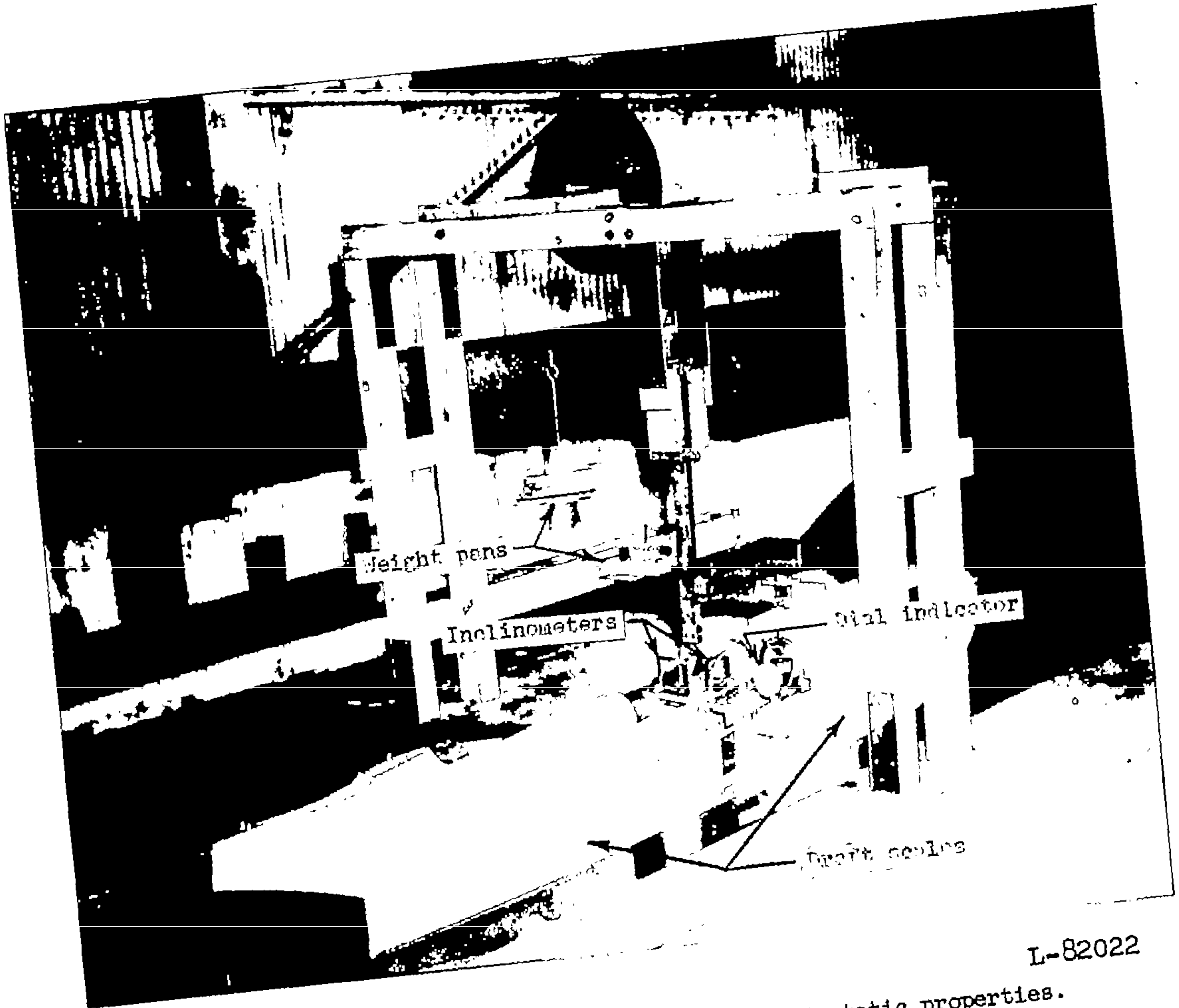
[b]Length-beam ratio of 15 with 40° angle of dead rise.

TABLE III

LOCATION OF CENTER OF GRAVITY FOR LANGLEY TANK NO. 1

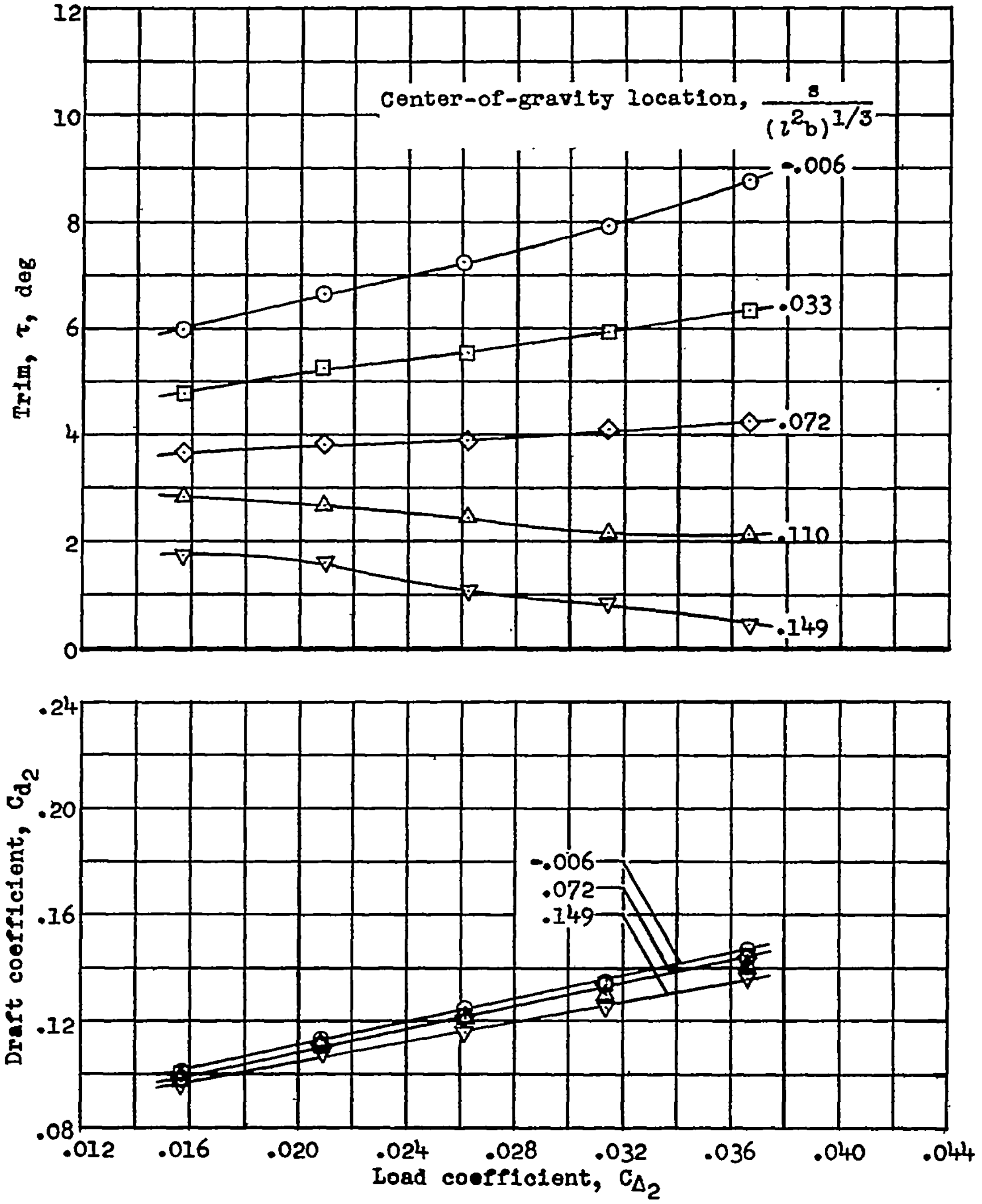
SERIES OF LENGTH-BEAM-RATIO HULLS

| Percent mean aerodynamic chord | Distance forward of step | | | | | | | Distance from bow | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ft (full size) | $\frac{s}{(l^2 b)^{1/3}}$ | Percent b for - | | | | | Percent $l$ for - | | | | |
| | | | $\frac{l}{b} = 3$ | $\frac{l}{b} = 6$ | $\frac{l}{b} = 12$ | $\frac{l}{b} = 15$ | $\frac{l}{b} = 20$ | $\frac{l}{b} = 3$ | $\frac{l}{b} = 6$ | $\frac{l}{b} = 12$ | $\frac{l}{b} = 15$ | $\frac{l}{b} = 20$ |
| 10 | 5.29 | 0.149 | 31.00 | 49.20 | 78.13 | 90.61 | 109.90 | 47.22 | 49.36 | 51.05 | 51.52 | 52.07 |
| 20 | 3.92 | .110 | 22.96 | 36.44 | 57.86 | 67.10 | 81.38 | 49.90 | 51.49 | 52.74 | 53.08 | 53.49 |
| 30 | 2.55 | .072 | 14.91 | 23.67 | 37.59 | 43.59 | 52.87 | 52.58 | 53.61 | 54.43 | 54.65 | 54.92 |
| 40 | 1.17 | .033 | 6.87 | 10.91 | 17.32 | 20.09 | 24.36 | 55.27 | 55.74 | 56.11 | 56.22 | 56.34 |
| 50 | -.20 | -.006 | -1.17 | -1.86 | -2.95 | -3.42 | -4.15 | 57.95 | 57.87 | 57.80 | 57.79 | 57.76 |



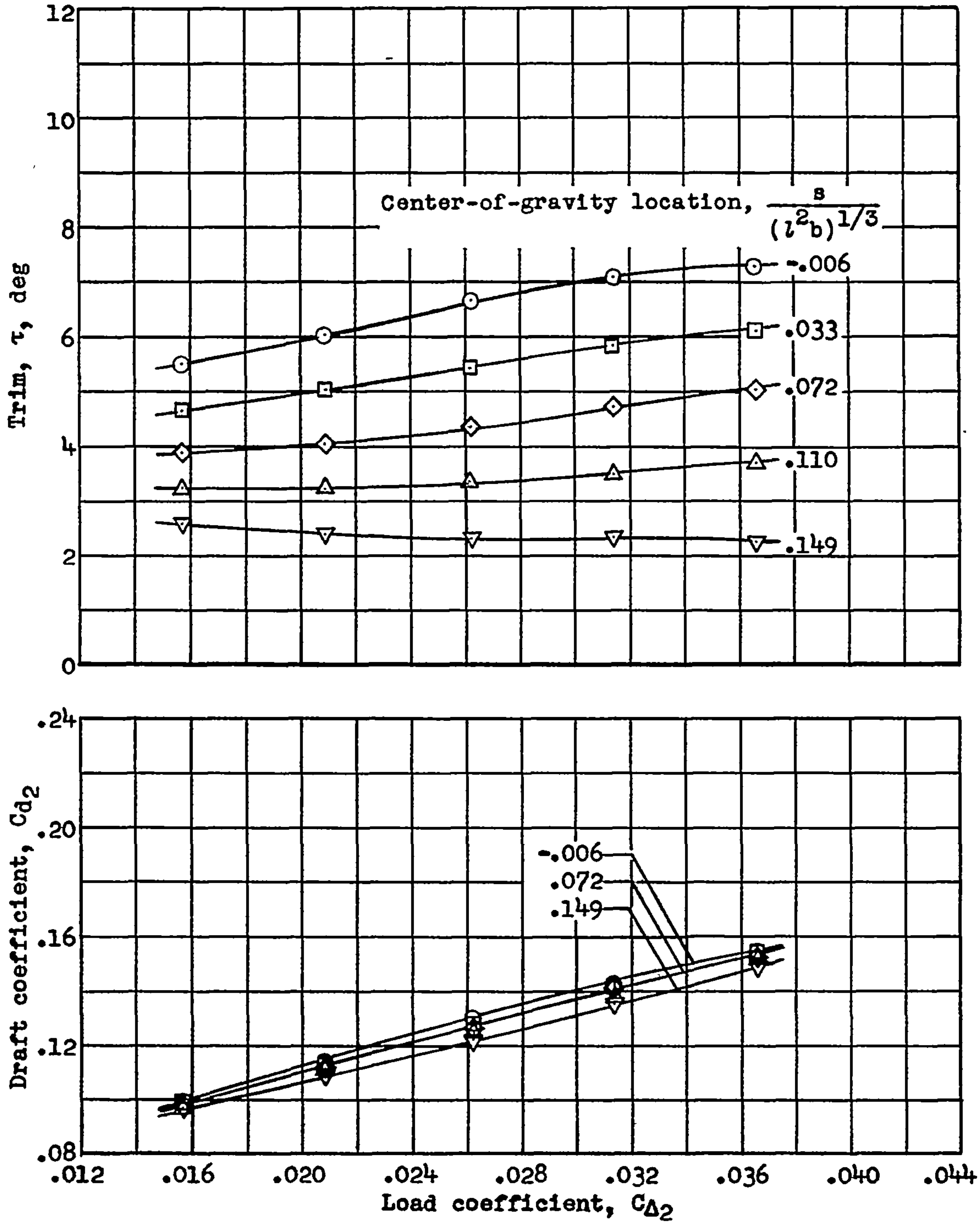

L-82022

Figure 1.- Setup of model for determination of static properties.



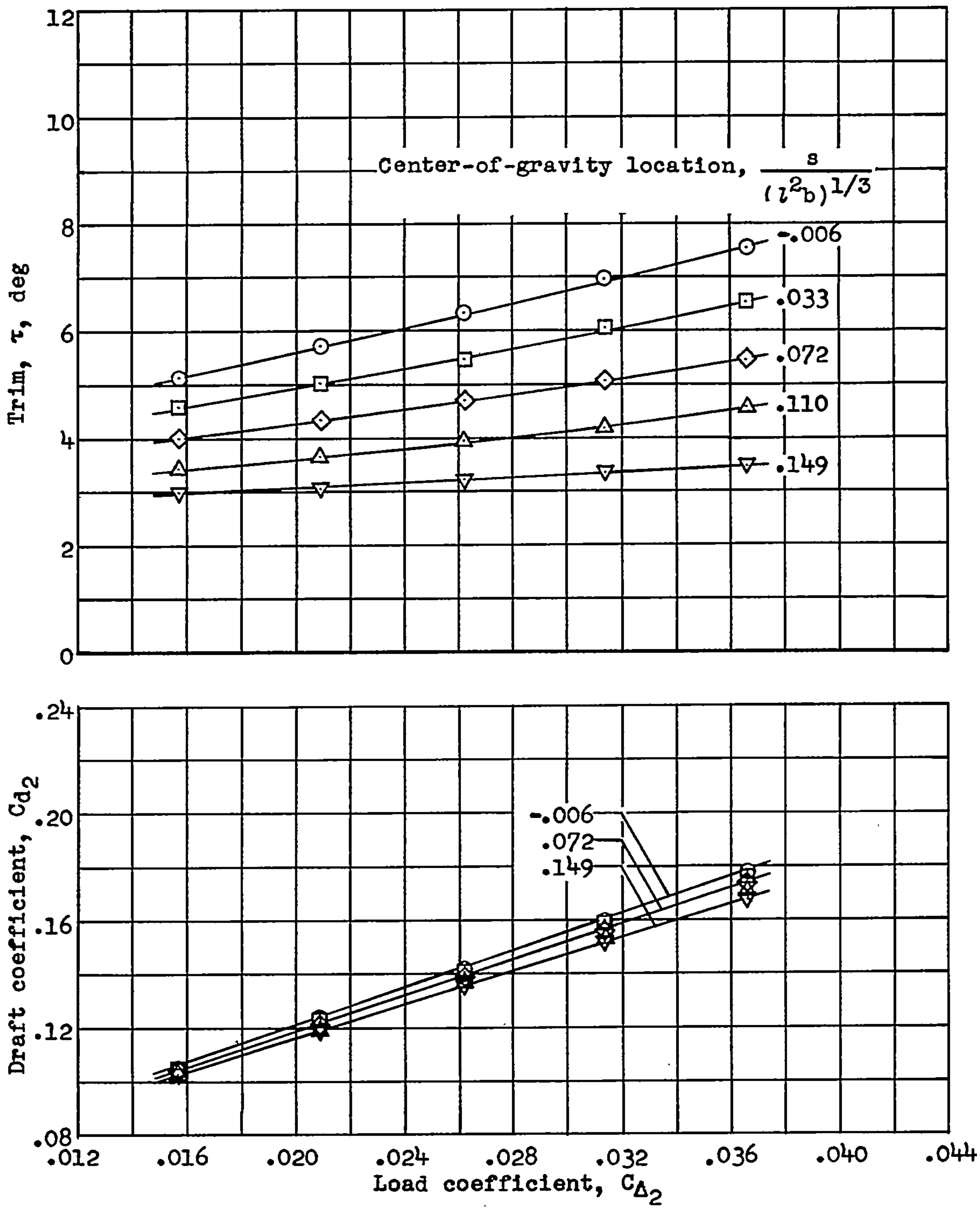

(a) Length-beam ratio, 3.

Figure 2.- Longitudinal static properties. $\phi = 0^{\circ}$.



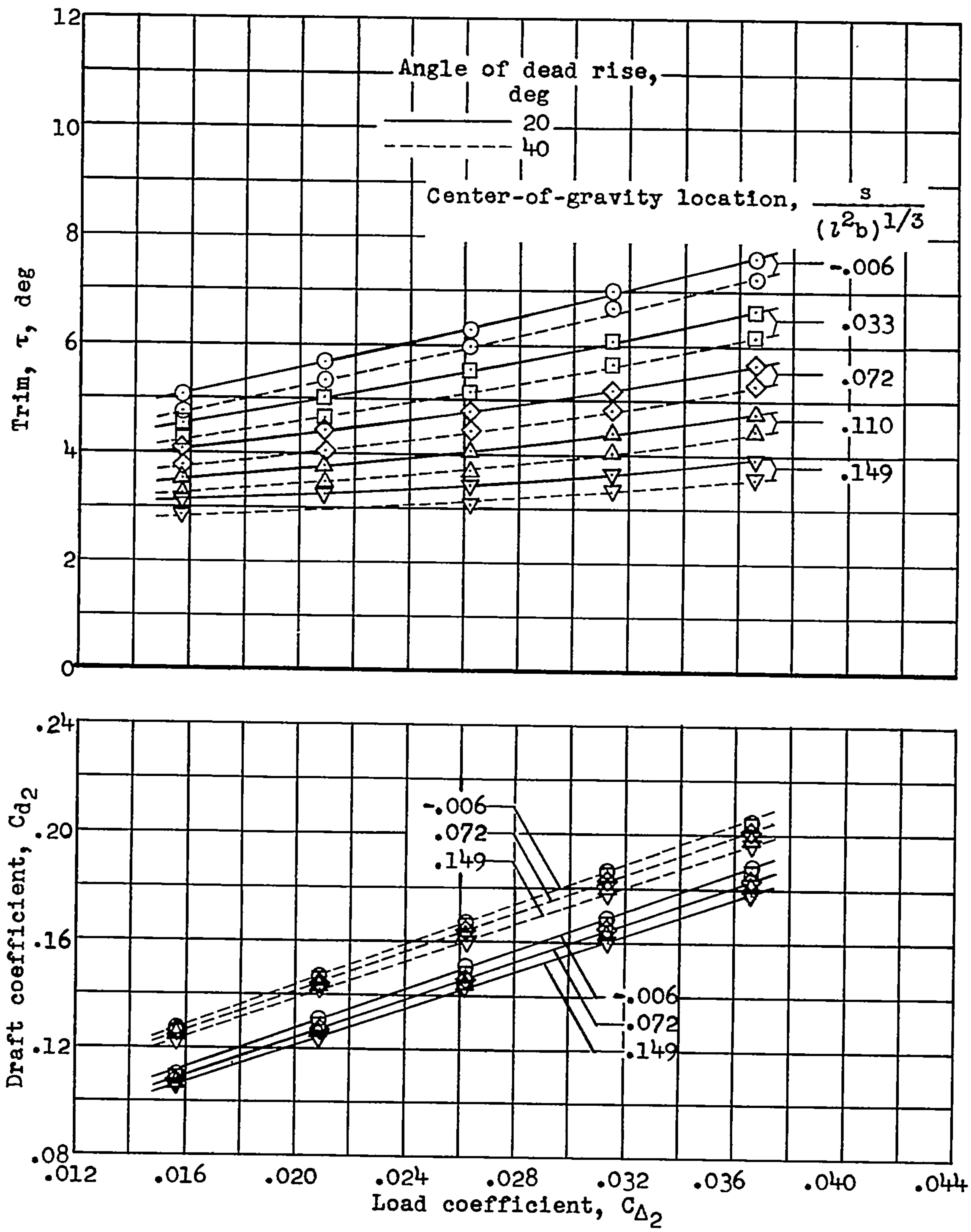

(b) Length-beam ratio, 6.

Figure 2.- Continued.



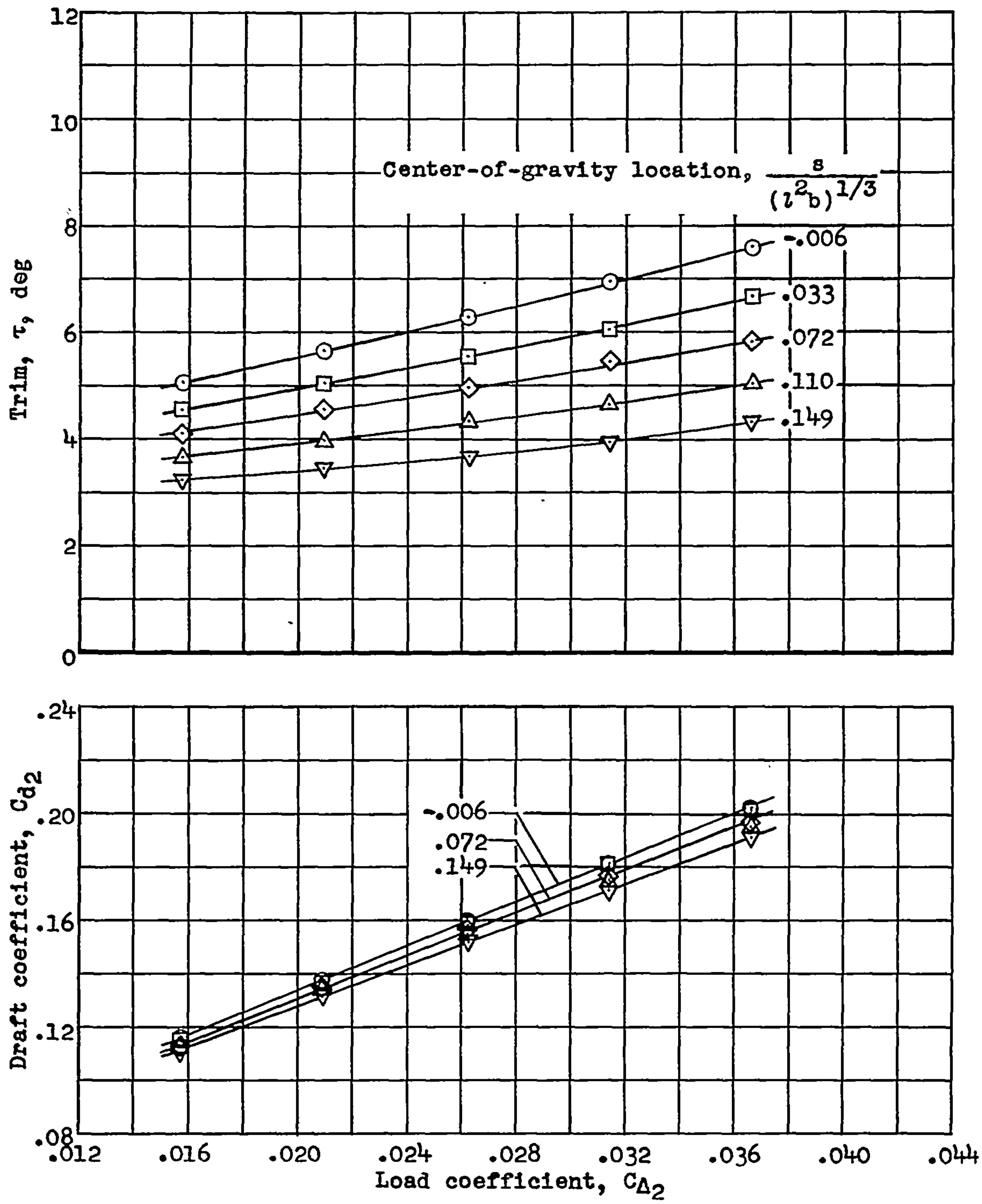

(c) Length-beam ratio, 12.

Figure 2.- Continued.




(d) Length-beam ratio, 15.

Figure 2.- Continued.




(e) Length-beam ratio, 20.

Figure 2.- Concluded.

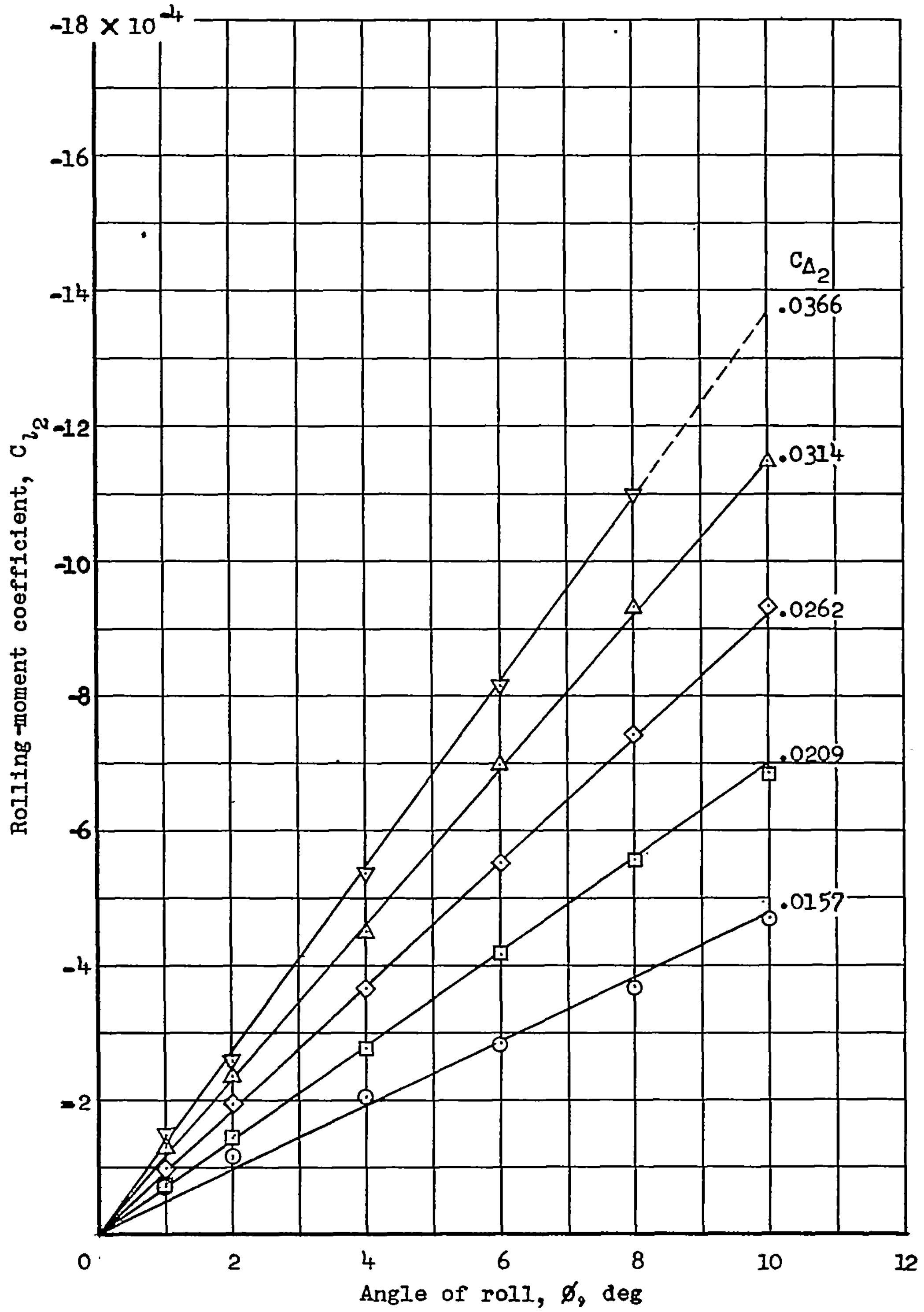



Figure 3.- Typical variation of rolling-moment coefficient with angle of roll. Length-beam ratio, 6.

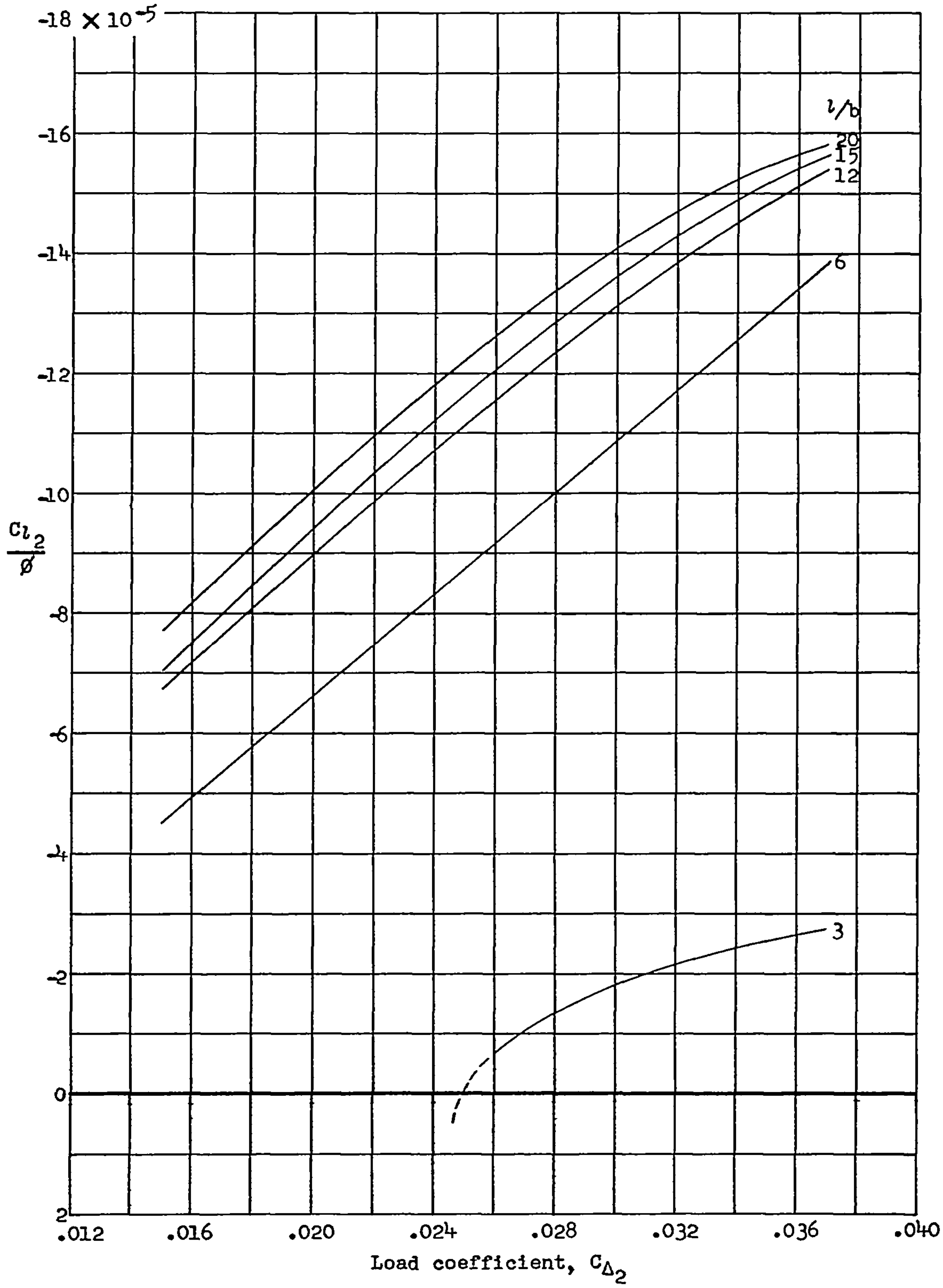



Figure 4.- Effect of length-beam ratio on slope of rolling-moment curve.

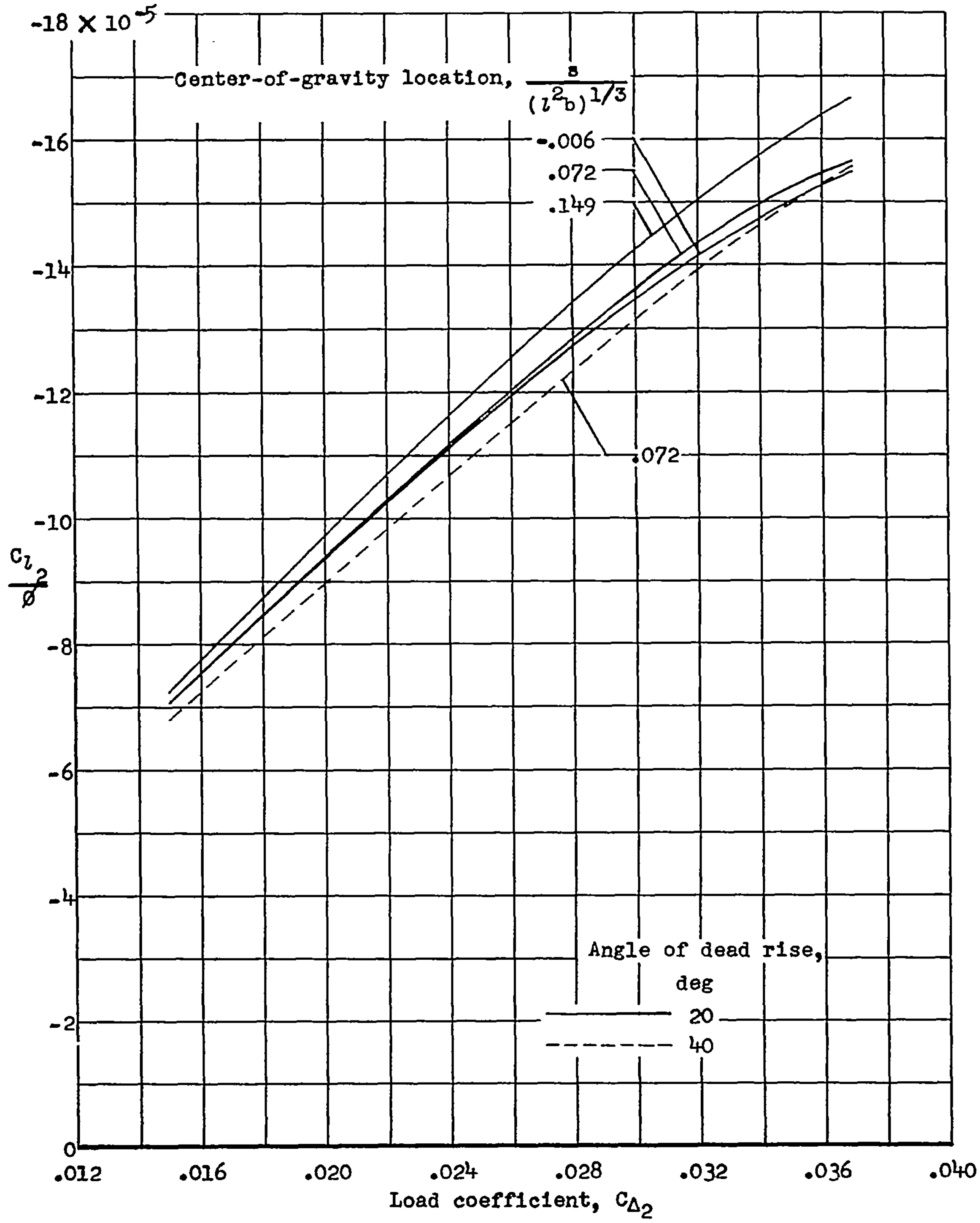



Figure 5.- Effect of center-of-gravity location and angle of dead rise on slope of rolling-moment curve. Length-beam ratio, 15.

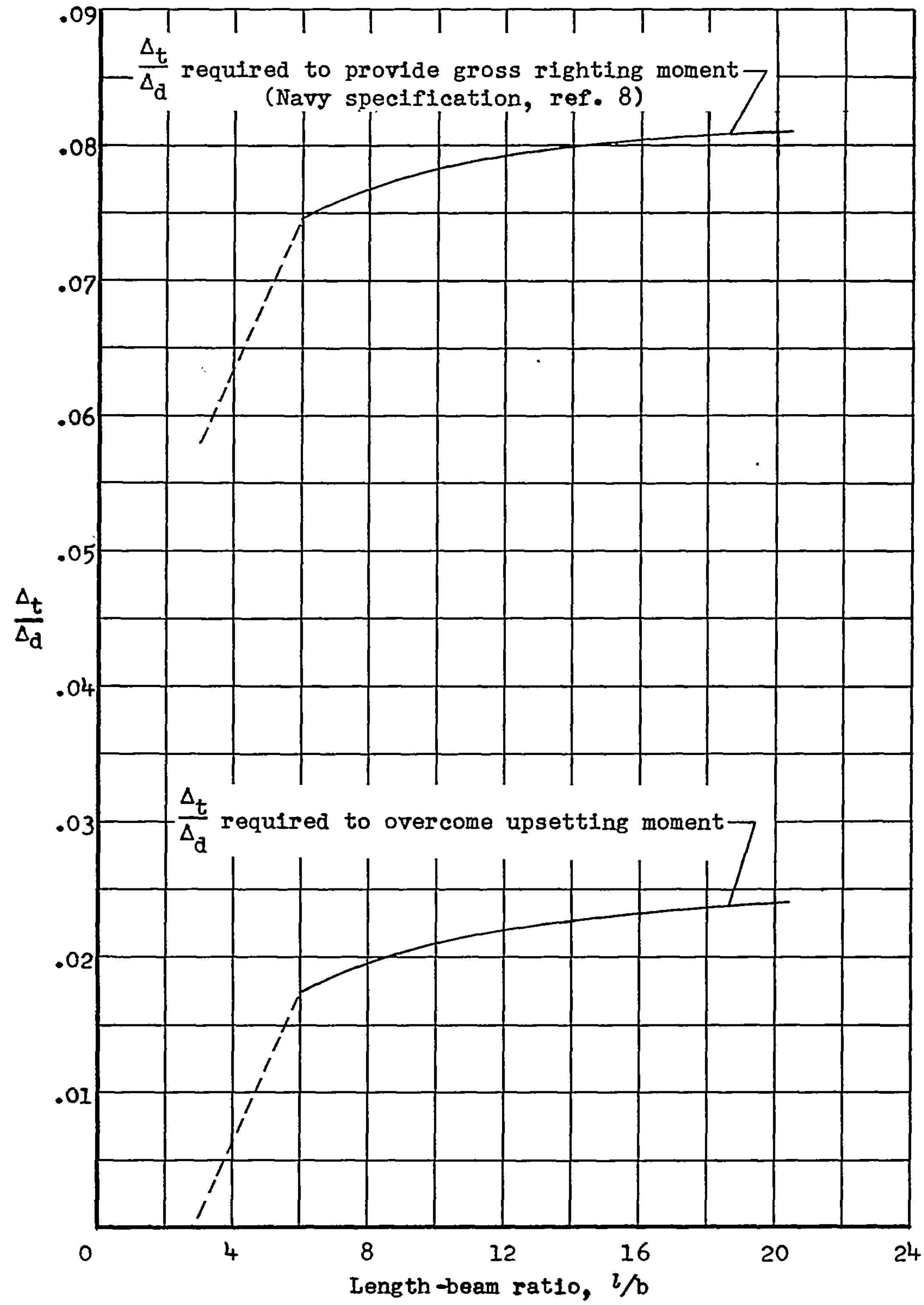
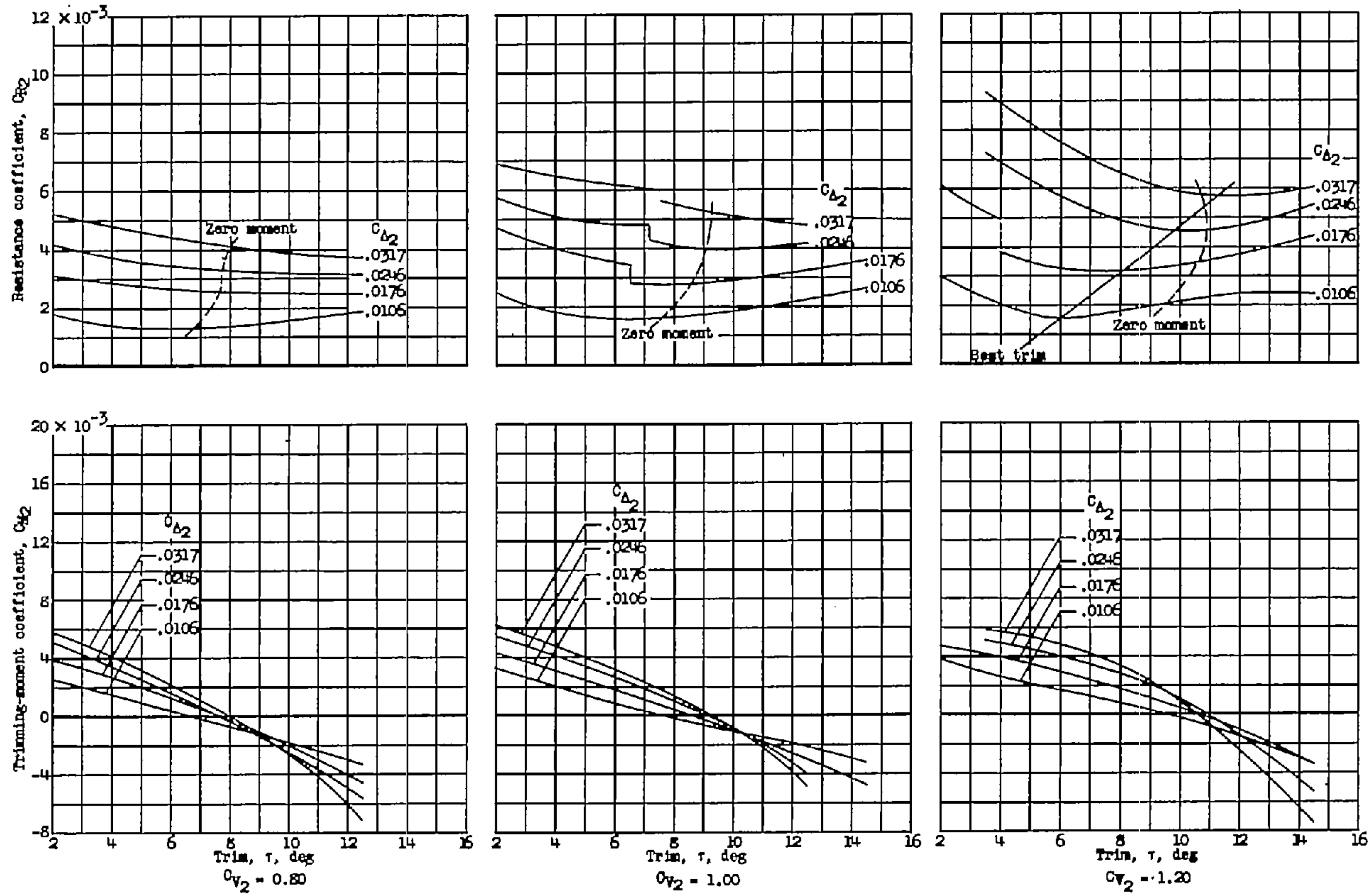
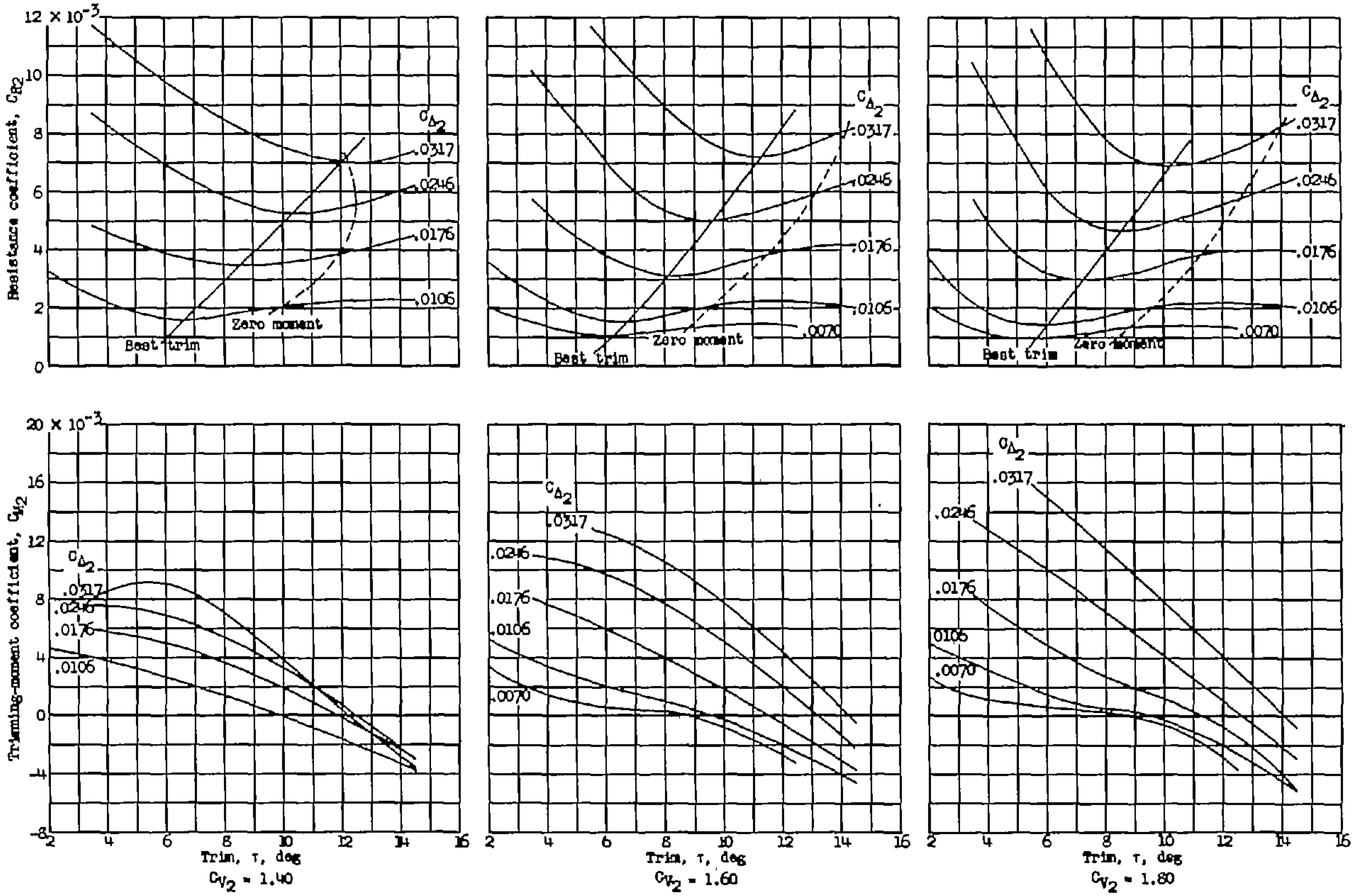



Figure 6.- Effect of length-beam ratio on righting and upsetting moments. $\phi = 7^\circ$.



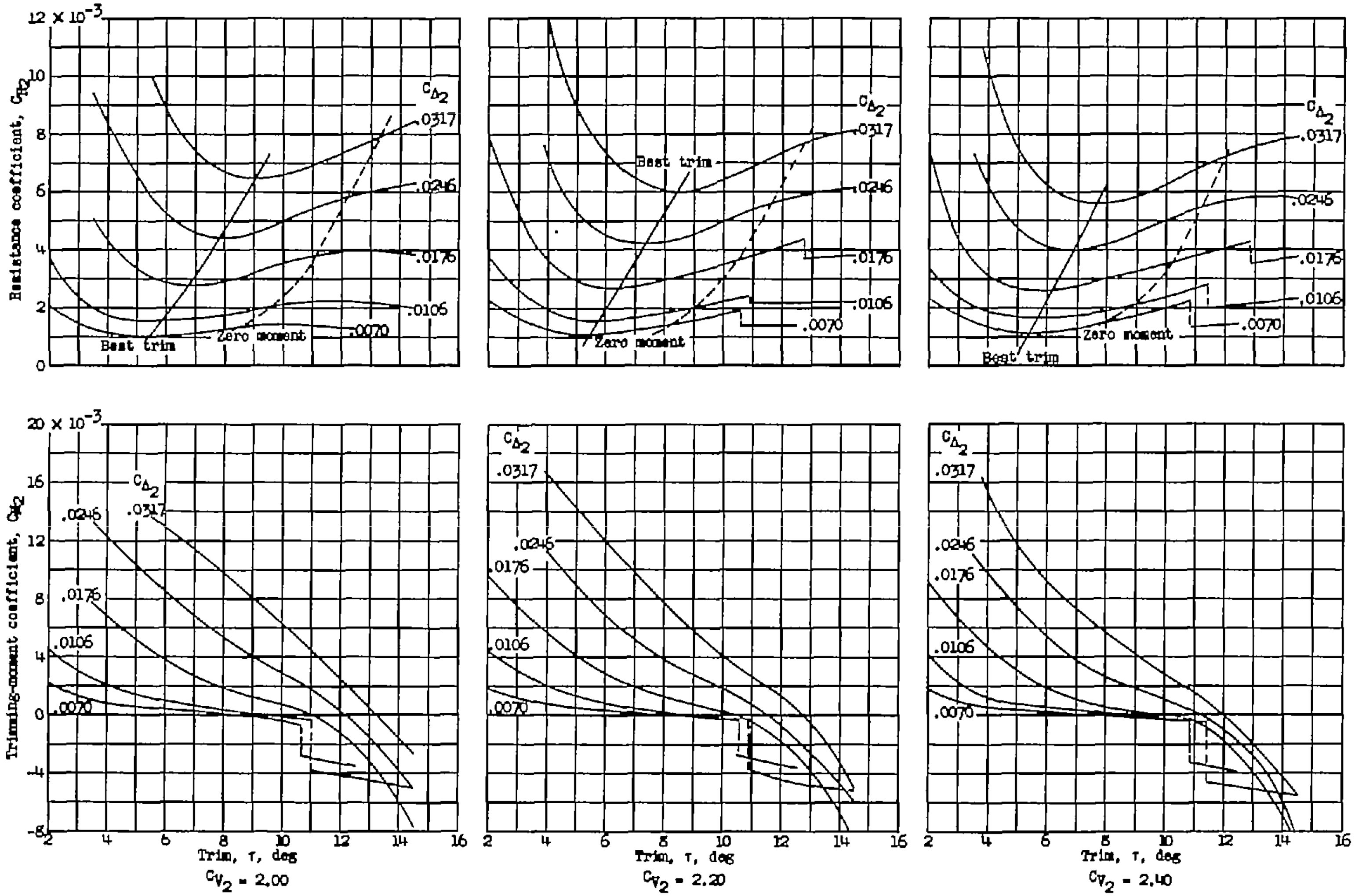

(a) Length-beam ratio, 6.

Figure 7.- Resistance and trimming moment. Fixed trim.



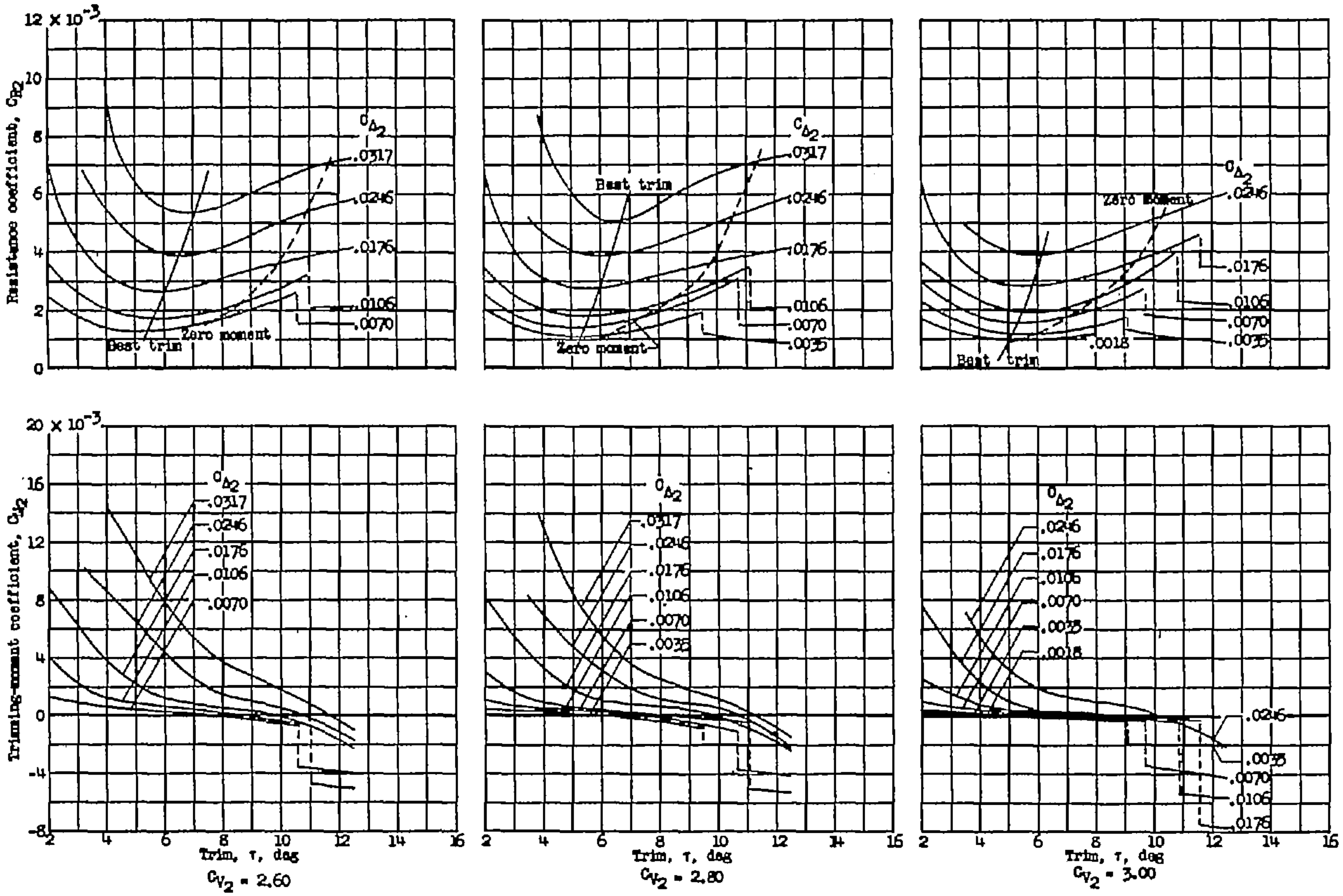

(a) Continued.

Figure 7.- Continued.



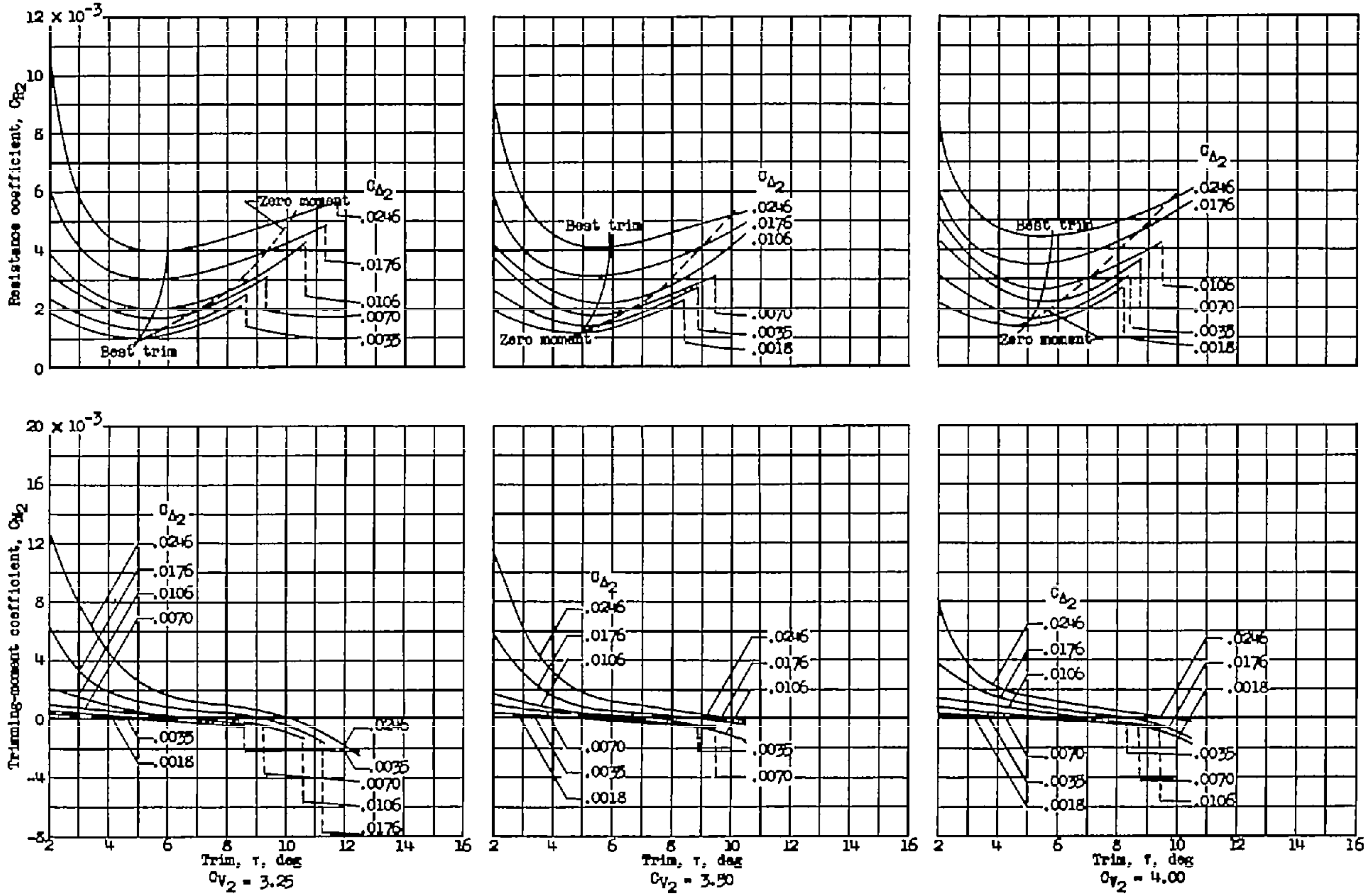

(a) Continued.

Figure 7.- Continued.



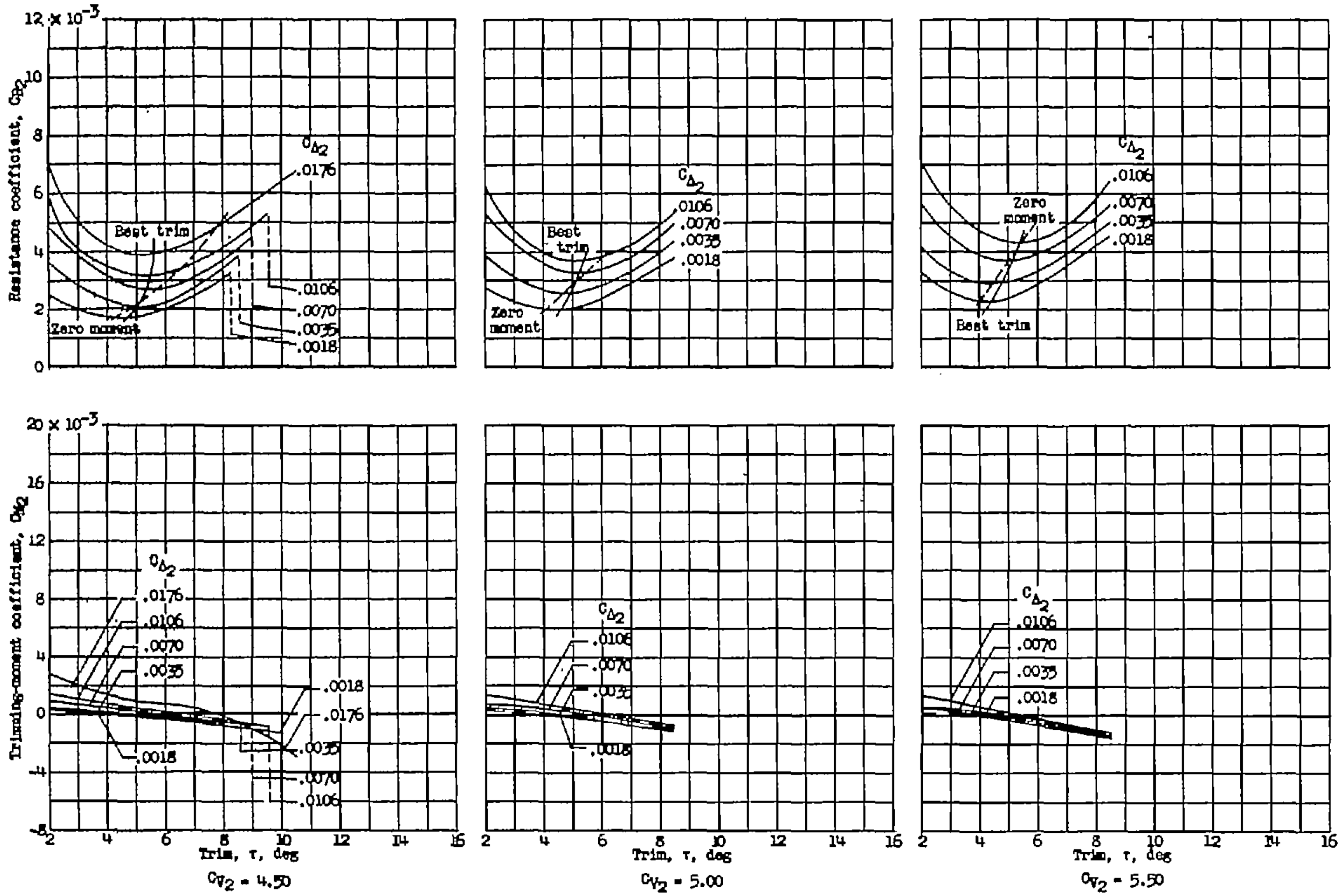

(a) Continued.

Figure 7.- Continued.



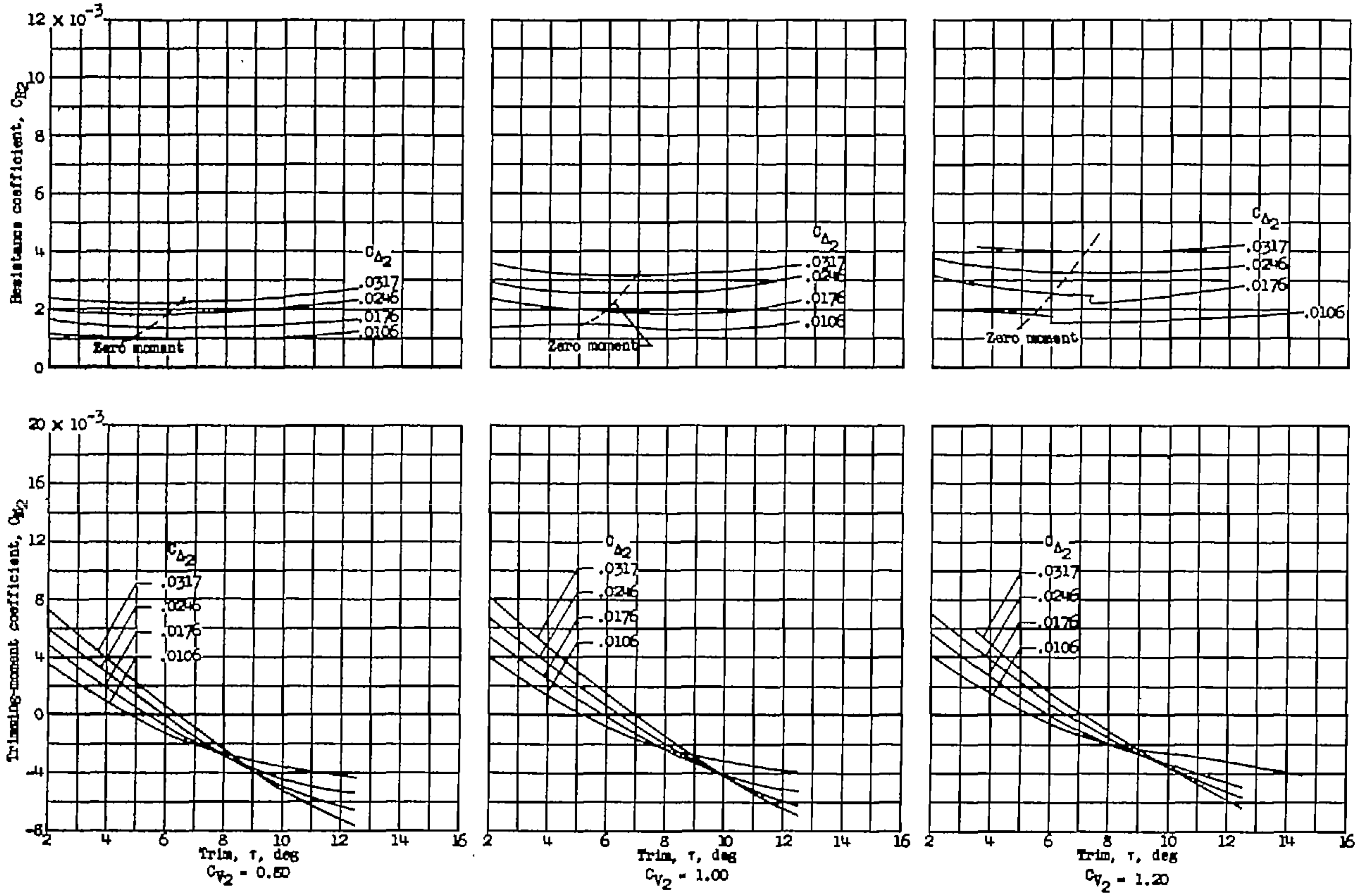

(a) Continued.

Figure 7.- Continued.



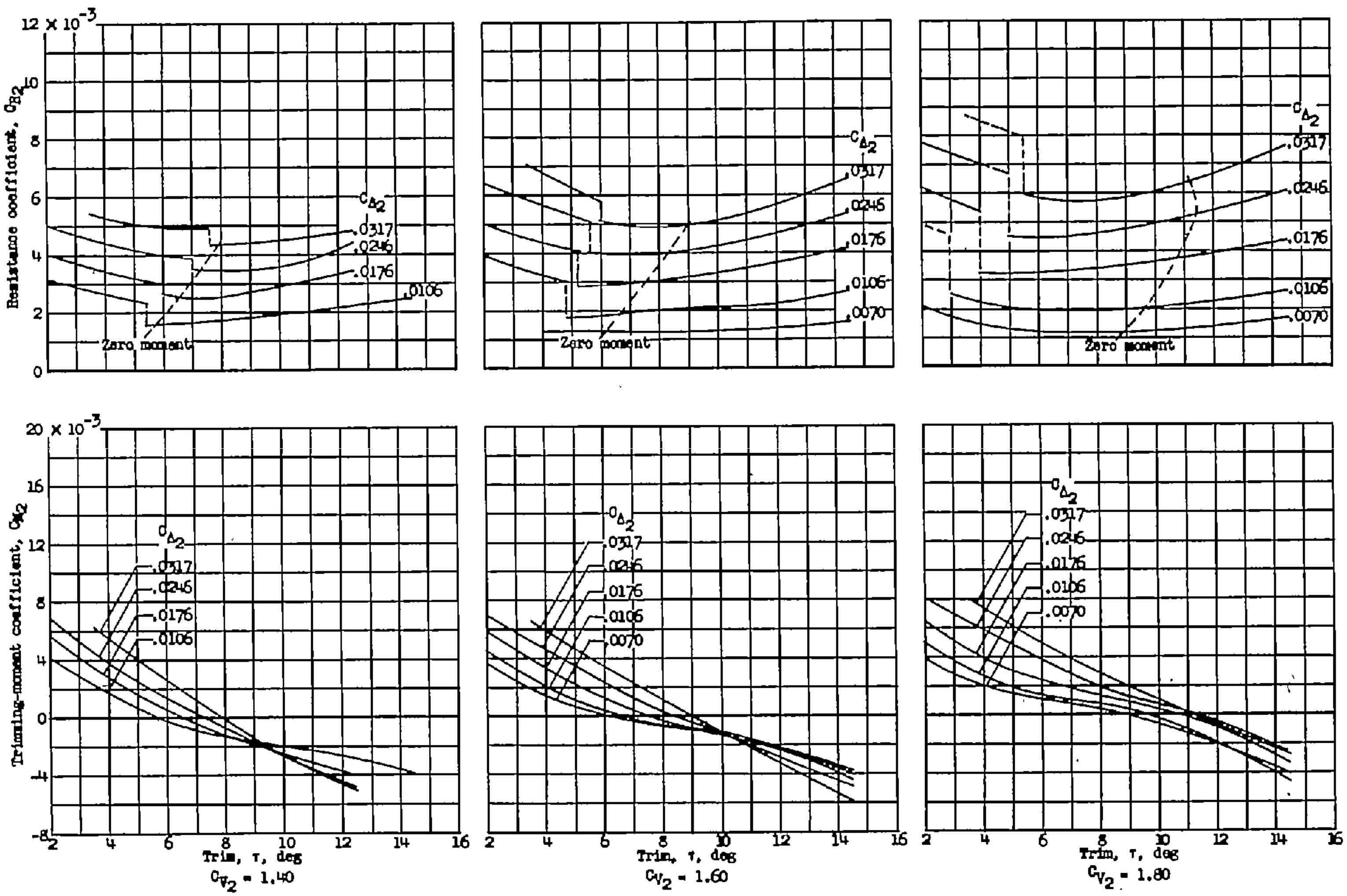

(a) Concluded.

Figure 7.- Continued.



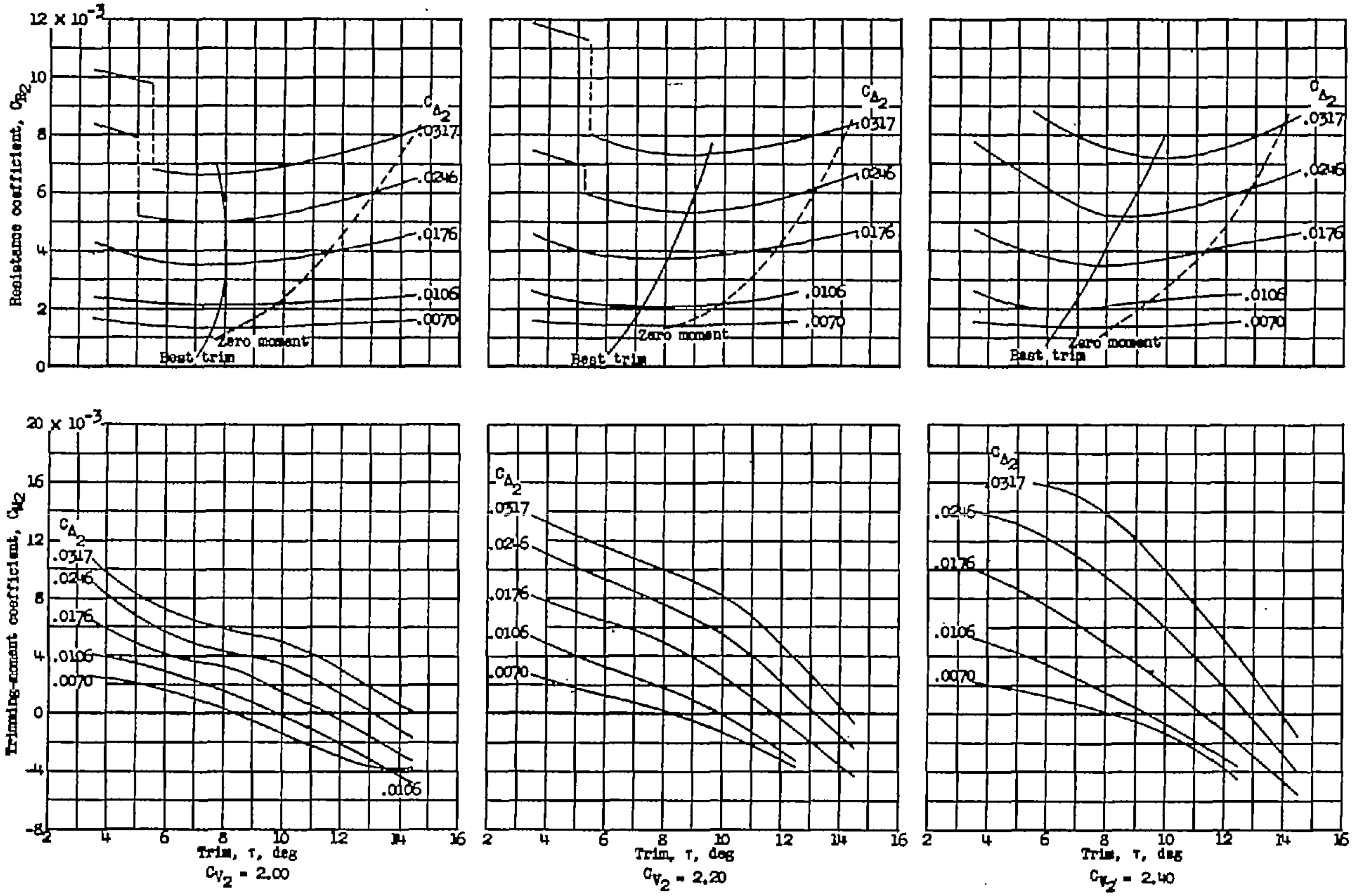

(b) Length-beam ratio, 15.

Figure 7.- Continued.



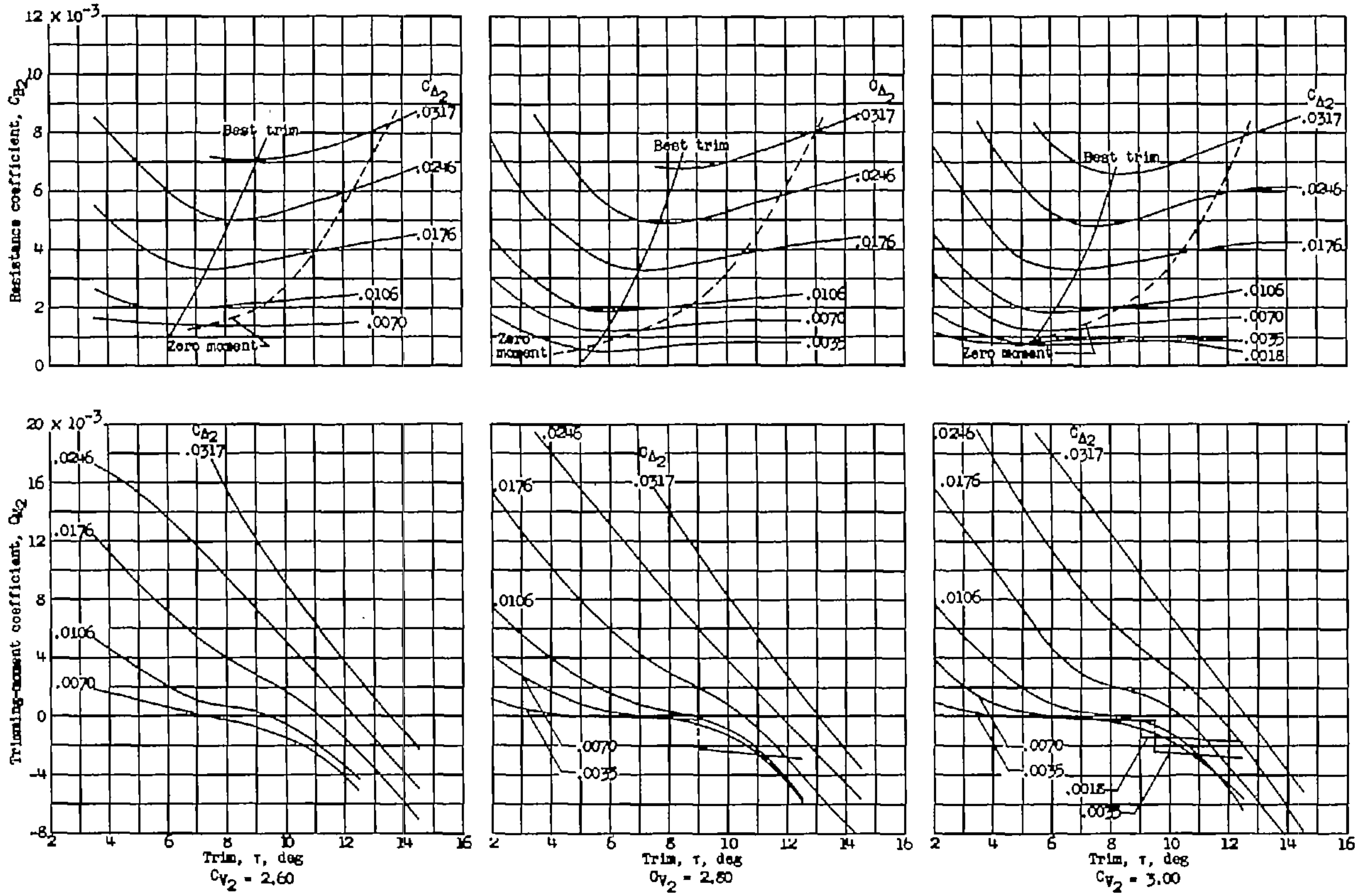

(b) Continued.

Figure 7.- Continued.



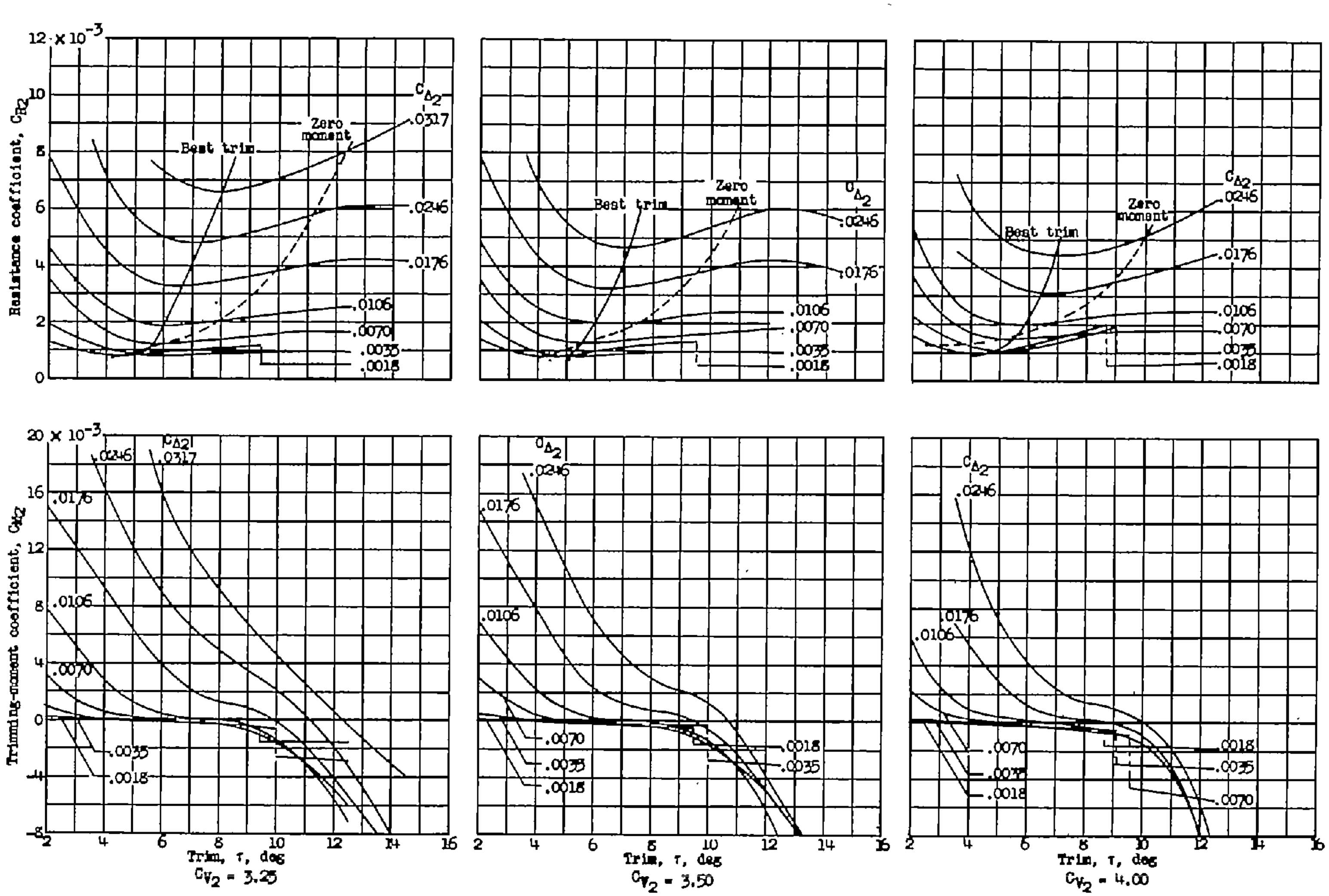

(b) Continued.

Figure 7.- Continued.



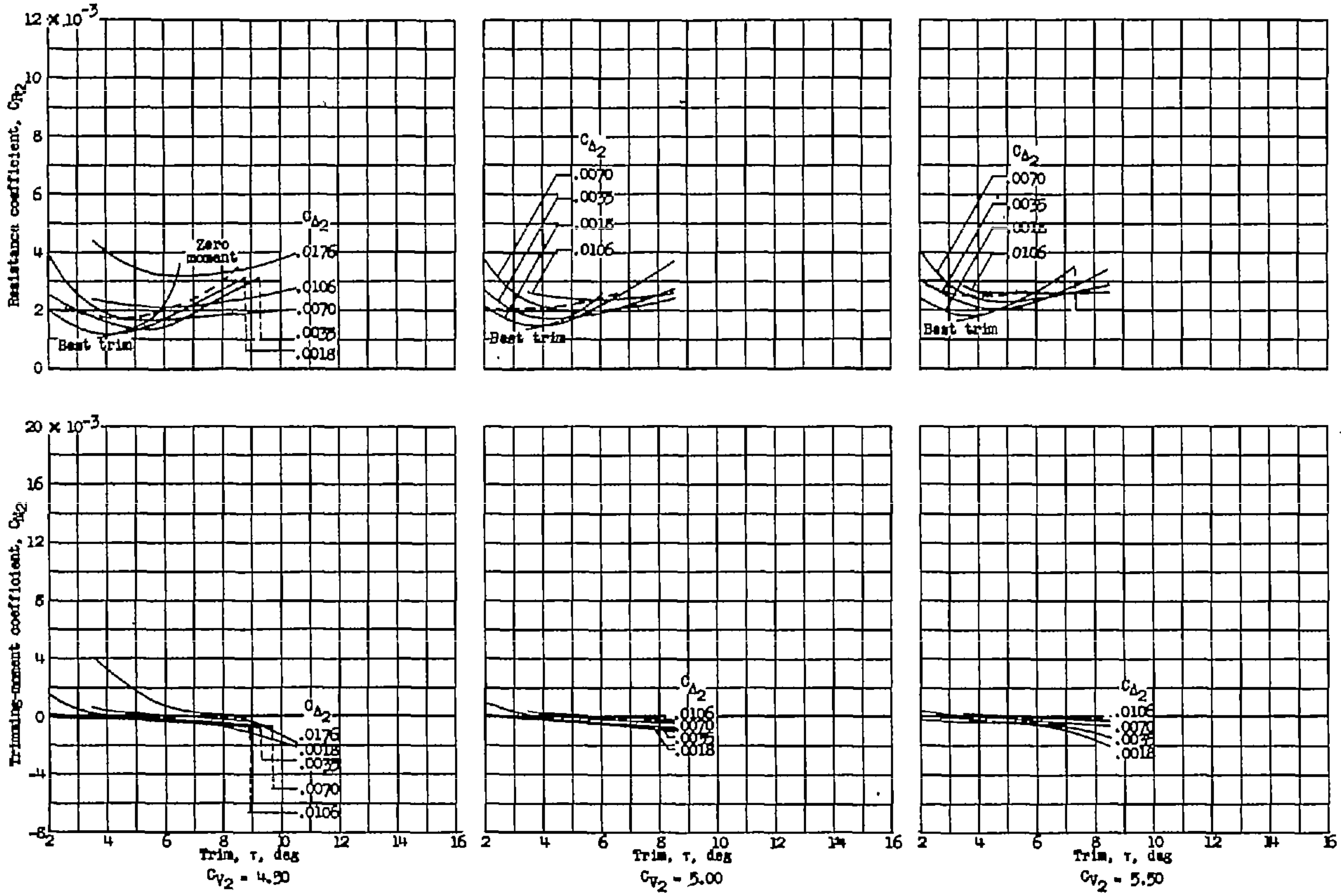

(b) Continued.

Figure 7.- Continued.




(b) Continued.

Figure 7.- Continued.




(b) Concluded.

Figure 7.- Concluded.

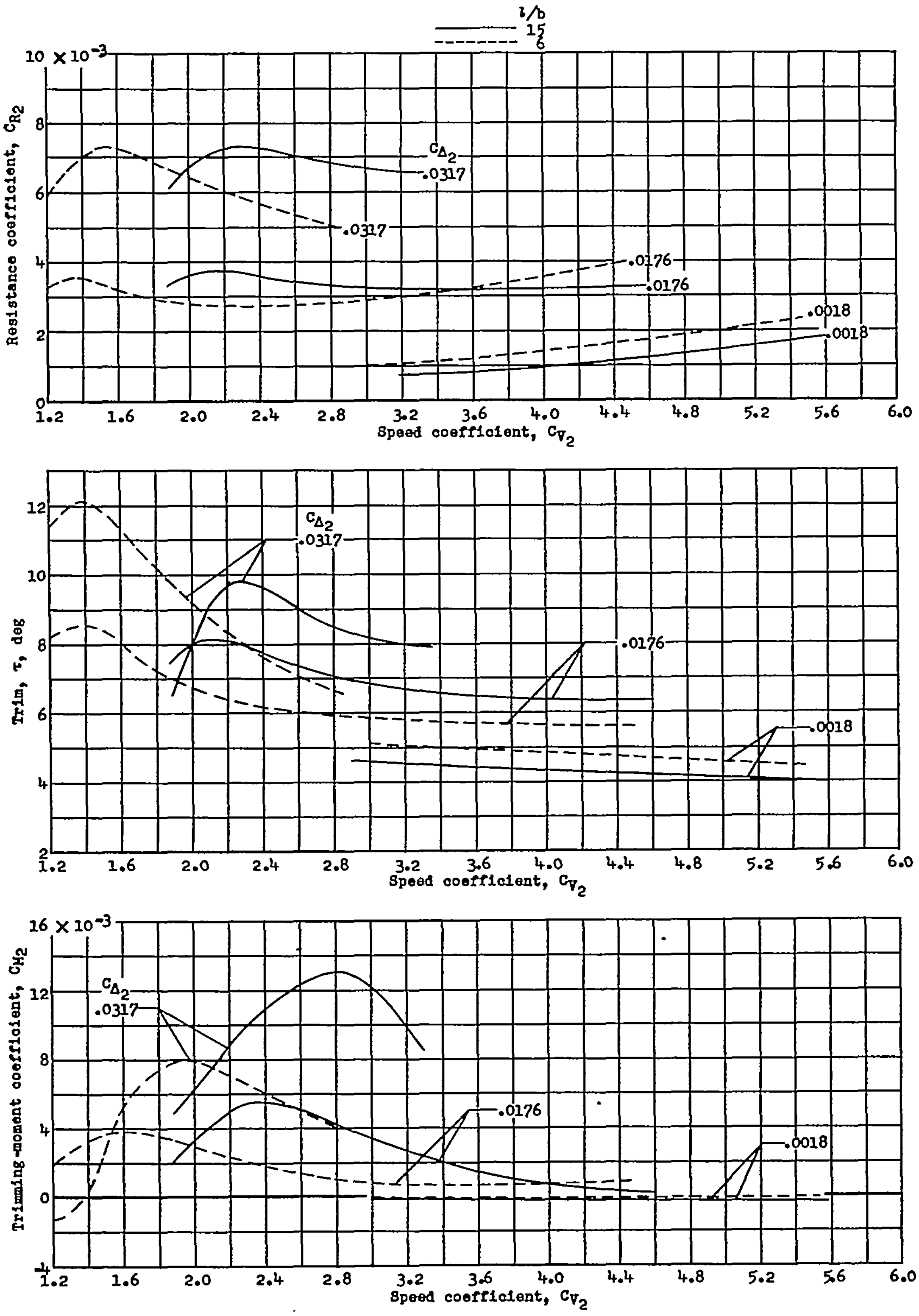



Figure 8.- Resistance and trimming-moment coefficients and trim at best trim.

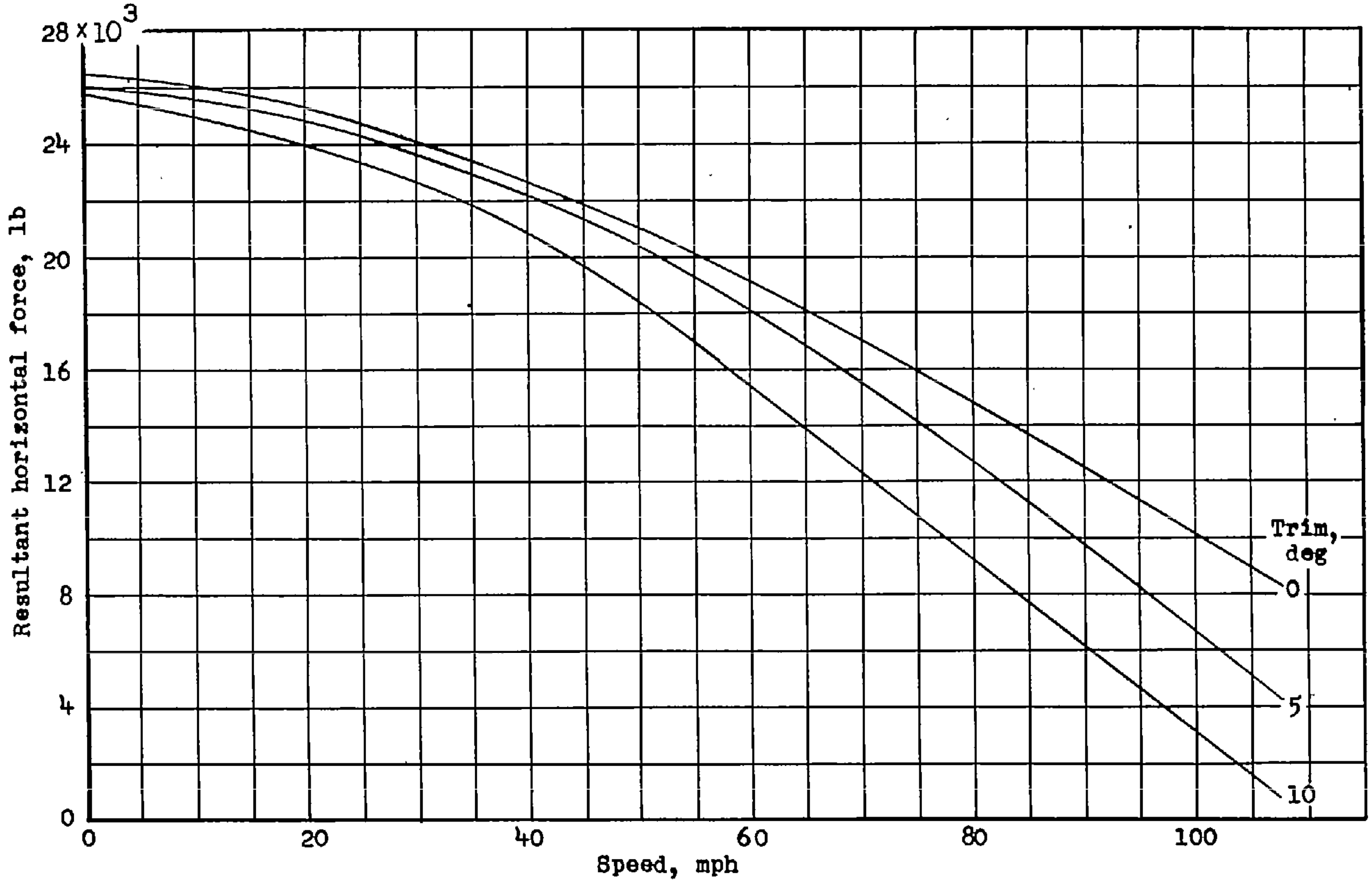



Figure 9.- Variation of resultant horizontal force with speed. Full thrust; flap deflection, 20°; elevator deflection, 0°; length-beam ratio, 15 (dynamic model).

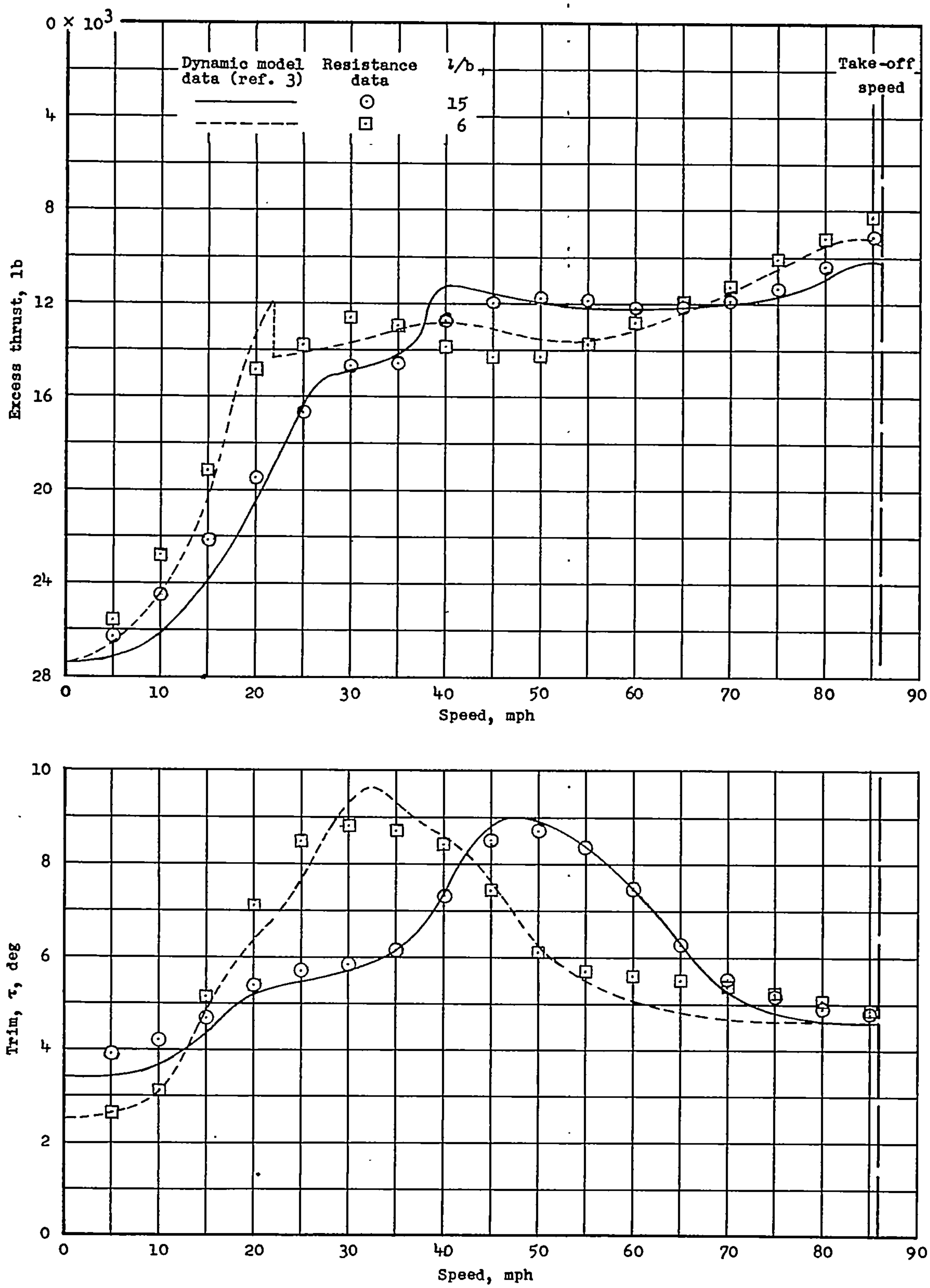
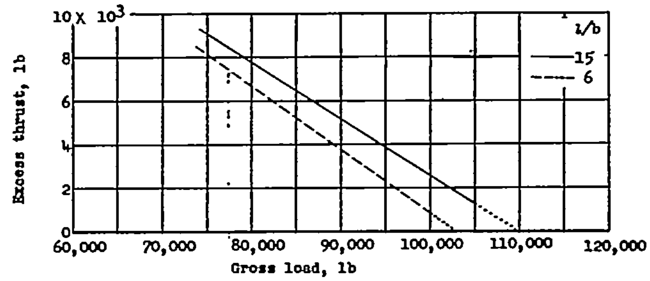
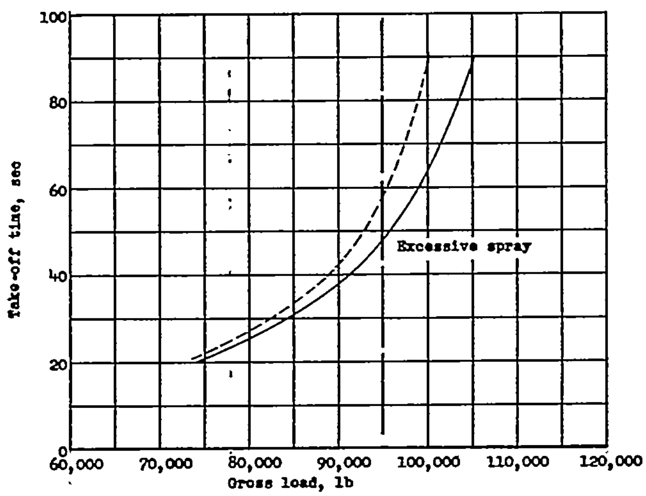


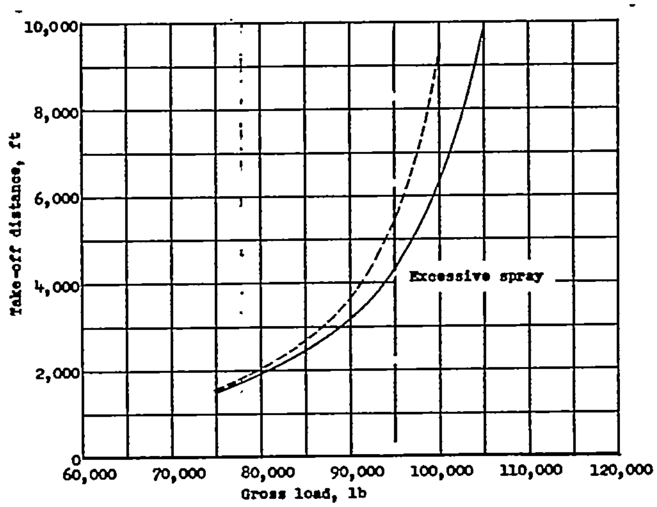

Figure 10.- Variation of excess thrust and trim with speed during take-off.




(a) Variation of excess thrust with gross load at take-off speed.




(b) Effect of gross load on take-off time.




(c) Effect of gross load on take-off distance.

Figure 11.- Summary of take-off calculations.